SPRING/SUMMER 2014
VOLUME 14, NUMBER 2
WWW.TIIJ.ORG

TIIJ International

Technology Interface International Journal

ISSN: 1523-9926

Philip D. Weinsier
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Published by the
International Association of Journals & Conferences

TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL

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THE TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL EDITORS

TABLE OF CONTENTS

EDITOR'S NOTE

Philip Weinsier, TIIJ Editor-in-Chief

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Indexed In

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 fourth IAJC conference, we will be partnering with the International Society of Agile Manufacturing (ISAM). This event will be held at the new Embassy Suites hotel in Orlando, FL, September 25-27, 2014, and is sponsored by IAJC, IEEE, ASEE, and the LEAN Institute. 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.

I am also proud to report that, based on the latest impact factor (IF) calculations (Google Scholar method), the Technology Interface International Journal (TIIJ) now has an impact factor of 1.02, placing it among an elite group of most-cited engineering journals worldwide. Any IF above 1 is considered high, based on the requirements of many top universities.

Conference Statistics: Of the submissions for this conference, there were 466 abstracts from 132 educational institutions and companies from around the world (multiple submissions from the same authors were not counted). This represented 48 of the 50 U.S. states and 49 countries were represented. After a multi-level review process, only 82 full papers and 19 abstracts were accepted for presentation at the conference and for publication in the conference proceedings. This reflects an acceptance rate of about 22%, which is one of the lowest acceptance rates of any international conference.

ISBN# 978-1-60643-379-9

Editorial Review Board Members

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

As we continually strive to improve upon our conferences, we are seeking dedicated individuals to join us on the planning committee for the next conference—tentatively scheduled for 2016. Please watch for updates on our website (**www.IAJC.org**) and contact us anytime with comments, concerns, or suggestions.

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

DESIGN FOR SUSTAINING: SUPPORTING POST-SALE LIFECYCLE ACTIVITIES THROUGH FUSED DEPOSITION MODELING

Y-hsiang Chang, University of North Dakota

Abstract

To ensure the proper operation of a product, sustaining activities such as maintenance, repair, or feature upgrade were performed regularly prior to the decommissioning of the product. The product owner, however, may have to retire it prematurely if parts for these sustaining activities are no longer available, unless a replica of the original or replacements that provide similar functions could be made in-house. The emerging 3D printing technology seems to bring in a new hope for those who could not afford to make their own parts in-house. Although current applications are mainly on producing prototypes for design visualization and evaluation, the recent advance of 3D printing technology in product quality and material diversity presents a huge potential for companies to reevaluate their internal product sustaining strategies. With the intention of bridging the gap between various research efforts and industry's best practices, the author investigated the feasibility of utilizing parts made via Fused Deposition Modeling (FDM) processes to support the need of post-sale product feature upgrades. The theoretical research of FDM and the best practices for mechanical part design were reviewed. Two cases on adding features to existing products were presented. The legal concern of reverse engineering was also discussed. This study concluded with an overview of recent FDM innovations and potential applications.

Introduction

Product lifecycle activities, according to Chang and Miller [1], can be divided into four different stages: Design, Planning, Manufacturing, and Sustaining (see Figure 1). The design stage started from the conceptualization of a new or revised product and progressed to the testing stage of the physical prototypes. Once completed, the design information was passed to the planning stage, where the activities of process planning and production planning occurred. The manufacturing stage consisted of activities prior to the delivery to the customer including part fabrication, assembly, quality assurance, packaging, etc. When the finished product was delivered to the customer, the product's lifecycle entered the sustaining stage.

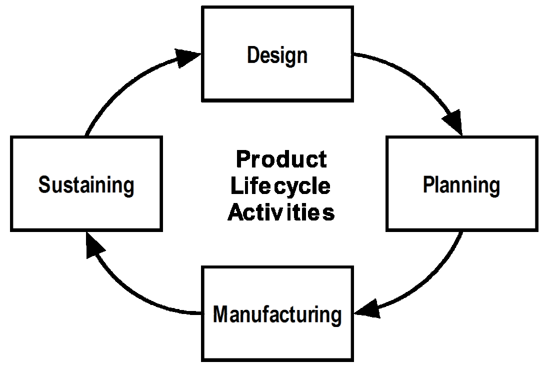

Figure 1. Different Stages of the Product Lifecycle Activities

Depending on the purpose and features of the product, the objective of the sustaining stage could be as simple as meeting design specifications by replacing the consumables, retrieving a spare by salvaging still-usable components, or as complicated as upgrading or performance improvement. Through the effort of original-equipment-manufacturer (OEM) or third-party vendors, the lifespan of the product may be extended beyond its design specification. The customer could be out of luck, however, if a spare from an OEM or a compatible part from a third-party vendor was no longer commercially available. Without proper in-house sustaining actions, the product might retire prematurely.

In-house sustaining actions refer to the customer's ability to replicate the part needed or to enhance the product by modifying critical components. Such actions, legally allowed, are often taken to meet the product user's internal needs instead of generating profit through reselling of the proprietary parts. Due to the lack of specific product knowledge and resources, few customers in the past were able to perform such actions. However, the increasing online accessibility of product information (either provided by OEM, third-party vendors, or public forums and DIYers' blogs) and the availability of affordable 3D printing devices have changed the situation [2]. On the one hand, the increasing availability of product information, while not necessarily providing detail such as material used or part dimension, shades the light of how the product works and leads to tips and traces of its design intent. On the other hand, 3D printing technology opens a new avenue for design realization. Consumers are freed from the issues of manufacturing complexity and skilled manufacturing, and are empowered by the ability to utilize infinite shades of materials and to create precise physical replications [3].

To better understand this phenomenon and its broader impact on industry, the goal of this study was to investigate the potential of polymer-based Fused Deposition Modeling (FDM), the most popular form of 3D printing technology supporting post-sale lifecycle activities. The theoretical research related to FDM and the best practices published by field practitioners were reviewed, and two cases of design for sustaining were discussed to connect theory with best practices. The legal concern of practicing reverse engineering in the context of 3D printing was also examined.

3D Printing, FDM, and Reverse Engineering

While stereo lithography was invented in 1984 by Charles Hull, 3D printing technology did not receive enough attention from the general public until 1992, a time when 3D Systems started rolling out of the first SLA machine. Solid free-form fabrication systems emerged, with the support of different additive processes and prototyping materials [4]. Pham and Gault [5] studied the strengths and weaknesses of thirteen different rapid prototyping technologies by comparing process parameters including layer thickness, system accuracy, and speed of operations. Levy et al. [6] classified six different additive processes for rapid manufacturing and rapid tooling purposes. Based on material preparation and shape forming strategies, the term "3D printing" was defined as the process to "drop (material) on bed".

It was not until 2005, when Dr. Adrian Bowyer founded RepRap [7], that the era of open-source 3D printing started. Compared to other layer manufacturing technologies such as stereo lithography (SLA), Solid Ground Curing (SGC), Laminated Object Manufacturing (LOM), and Selective Laser Sintering (SLS), Fused Deposition Modeling (FDM) became the dominating 3D printing technology, due to its lower cost of ownership. Utilizing the X-Y table principle, material of pre-made filaments was heated, extruded, and distributed on a heated platform. Once the printing of a level was finished, the platform was lowered to the next level and the printer head moved to where the material was needed and started the thermo-deposition process again.

Research on different aspects of FDM has been reported. Nevertheless, mechanical properties and surface finish of the printed parts were crucial in terms of supporting a product's post-sale lifecycle activities. As FDM constructed 3D objects via staking 2D layers, FDM parts' mechanical characteristics were different from those of parts created by conventional fabrication methods. Kulkarni and Dutta [8] studied both contour and raster deposition strategies and developed the mathematical models to determine part stiffness. Bellini and Güçeri [9] proposed an approach to predict the tensile strength of FDM parts; the tool path and corresponding test specimen were considered in order to construct ABS's stress-strain curves. Sood et al. [10] studied the change of stress-strain curves by controlling five different process variables: layer thickness, orientation, raster angle, raster width, and air gap. Lee et al. [11] reported the measurement of the anisotropic compressive strength of FDM parts, quantifying the strength difference between axial FDM and transverse specimens. Croccolo et al. [12] developed an analytical model of the mechanical behavior of FDM parts made of ABS-M30. Smith and Dean [13] published their findings of structural characteristics of FDM polycarbonate material, suggesting a more conservative part design with FDM, as the elastic modulus could be 45% lower and the tensile strength could be 30% to 60% lower than that of the vendor's data.

Surface finish or roughness of FDM parts, which essentially affected dimensional tolerance, could vary due to a variety of factors. In addition to the FDM process resolution claimed by system vendors, part orientation was a critical factor of resulting surface properties. Most recent FDM postprocessors allowed users to choose the orientation of the part; however, the options to reorient a part were limited and were often determined by the part's geometry. Masood et al. [14] reported the development of a generic algorithm to reduce volumetric error caused by different orientations. Thrimurthulu et al. [15] studied how to optimize part orientation by balancing surface finish and deposition time. To minimize the impact of part orientation, Galantucci et al. [16] proposed using chemical post-treatment in combination with modified extrusion parameters.

Tool path could also affect the surface quality of FDM parts. For each slice of the part, the postprocessor would generate a specific tool path for the printer head. Depending on the profile of each layer, the contour, raster, or a combination of both, path generation strategies might be used. When staked with the adjacent layers, the almost infinite combination of layer weaving patterns might create a less-desired surface finish. Han et al. [17] analyzed the overfill and underfill phenomena in order to manipulate the flow rate of FDM (e.g., traveling speed of the printer head) in order to achieve better surface quality. A mathematic model to represent surface roughness was reported by Ahn et al. [18]; driven by factors including cross-sectional shape, surface angle, and layer thickness, the model predicted surface finish, which was verified with empirical data.

To extract dimensional information of existing parts, the approach of reverse engineering, whether through a contact- or non-contact-based coordinate measuring machine (CMM), was often used to replicate or design parts needed for post-sale lifecycle activities. Lee and Woo [19] reported a system-integrated CMM and rapid prototyping technology, processing the data cloud to generate the sliced data for the rapid prototyping process. To reconstruct an organic surface, Zhongwei [20] proposed an algorithm for processing the scan data for the adaptive part-slicing strategy. Bagci [21] presented three cases using CMM to reconstruct replacement parts; while the resulting parts were built through CNC milling in this study, Bagci's reverse engineering approach seemed to be suitable for parts made of FDM as well.

Best Practice from Practitioners

With the popularity of low-cost 3D printers, a lot of "best practices" on how to design mechanical parts for 3D printing have been published online, especially on sites such as Shapeways (www.shapeways.com). The rule-of-thumb regarding wall thickness, shrinkage, tolerance assignment, clearance for post-printing polishing, and surfaces of moving parts were suggested and part variation caused by the FDM process itself—post-printing polishing, and painting—were reported [22], [23]. Martinson [24] discussed his experiments of printing three sets of functional mechanical assemblies, namely nut-and-bolt with threads, snap-fit pivots, and dovetail joints, in FDM. A study investigating the relationship between part design and actual parts created through Polyamid 12-based SLS printing was conducted by Sippel [25]. Tables of empirical data were used to show the connection between desired accuracy and actual production on part labels, wall thickness, pin size, gap size and hole size; there was, however, no mathematical analysis or theoretical explanation of why certain things happened. In conclusion, the actual quality of FDM parts was determined by multiple variables. These best practices, then, while not theory driven, served as a good entry point for beginners.

Case Studies

To further explore the potential of using FDM parts for post-sale product sustaining activities, two case studies were deployed. Based on the availability of resources, the focal point of these two cases was on product sustaining through feature addition, meaning the FDM parts were designed to add features to existing products. All of the parts were designed in SolidWorks, and the information for reverse engineering was obtained by measuring target products' dimensions with a dial caliper. The model of the FDM printing device used in both cases was uPrint SE by Stratasys, and the material used was ABSplus thermoplastic. The SolidWorks models were first converted into the standard STL format, and the option "Solid" was used for wall construction in order to achieve better structural strength. Part orientation for all parts in the cases was selected in a way the minimum amount of supporting material was used.

Case One: The Conversion Cover

The first case examined, as shown in Figure 2, was to design a conversion cover for an existing Solid State Drive (SSD) to reduce the housing thickness from 9 mm to 7 mm. The finish of most of the part's surface was not critical, and the majority of the cover design resembled the existing black cover in order to retain structure integrity. The key change made was to lower the side wall in order to achieve a total height of 7 mm, once assembled. Four U-shaped slots were used to fit the bosses housing the screw holes on the counterpart enclosure, and the screw holes were placed to align with their current locations. As the dimension of the resulting part suggested, this case was to test the printer's limitations against the rule-of-thumb on the size and location of gap, pin, hole, and wall features.

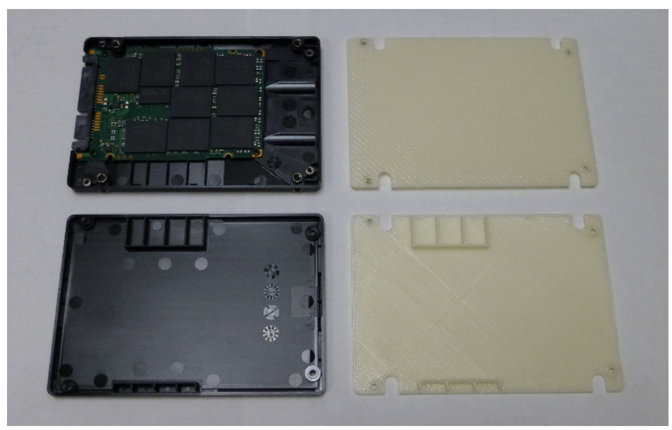

Figure 2. The Conversion Cover Printed for the SSD (Left)

Figure 3 shows the sixth revision of the convert cover. While the reverse engineering activity via a caliper went well, a lot of design details necessary for proper assembly (instead of perfect) were not clear until multiple revisions of the original design were printed. For example, the location of the circled U-shaped slot was off due to material shrinkage and process variation. A larger slot was eventually used to provide necessary clearance [22], [23]. The other example was the small slots circled in the figure. The size and location of these slots needed to be "guesstimated", due to non-uniform material shrinkage, unless the user intended to remove the spacers from the existing counterpart enclosure.

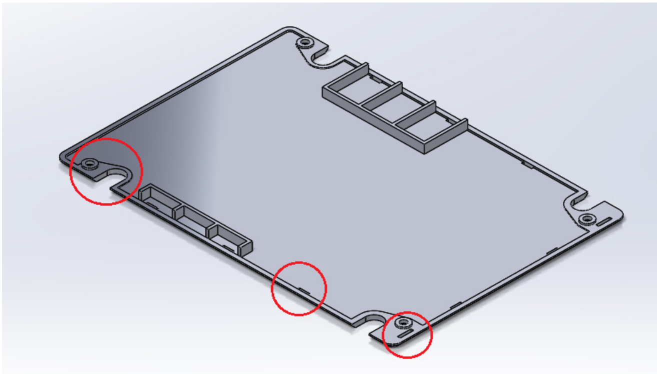

Figure 3. The Sixth Revision of the SSD Cover Design

Another issue of multiple revisions came from the correct alignment of screw holes. The boss shown at the bottom of Figure 3 was necessary to house the counter-bored hole on the reverse side. The screw hole was presented in the initial design attempt, but the resulting part showed a defective boss, due to the wall thickness. A design revision was to drill the screw holes afterward, but the process variation made the matching of the counter-bore and existing screw holes very difficult. Eventually, a pre-made hole, which might not be printed properly due to the printer's resolution, was used to guide the post-printing drilling. The overall time for part designing and testing was 10 hours, including all six revisions; the printing time for individual parts was around 25 minutes, depending on features to be included.

Case Two: The Antenna Fixturing System

Shown in Figure 4, a fixture was designed and printed to support antenna testing in the over-the-air (OTA) wireless test chamber. To get reliable test results, the test chamber needed to be calibrated for different frequencies prior to actual antenna testing; both the vertical and horizontal arms would rotate 360 degrees during baseline calibration and actual antenna testing. The calibrating antennas owned by the university came from different vendors, and the current solution was to use rubber bands to attach different calibrators to the horizontal arm. There was a need to create a fixturing system that could provide reliable positioning, while accommodating all four calibrators (see Figure 5).

The modular fixturing system shown in Figure 6 was developed to address this need. The main fixture (circled) was designed to attach to the horizontal arm using an internal locking mechanism. The other modular fixtures were designed so that the one side was attached to the tail of an antenna with screws, while the hollowed supporting arm from the main fixture could fit into the slots on the other side. The design of the main fixture was based on the existing structure of the horizontal arm; its supporting arms were hollowed to save material.

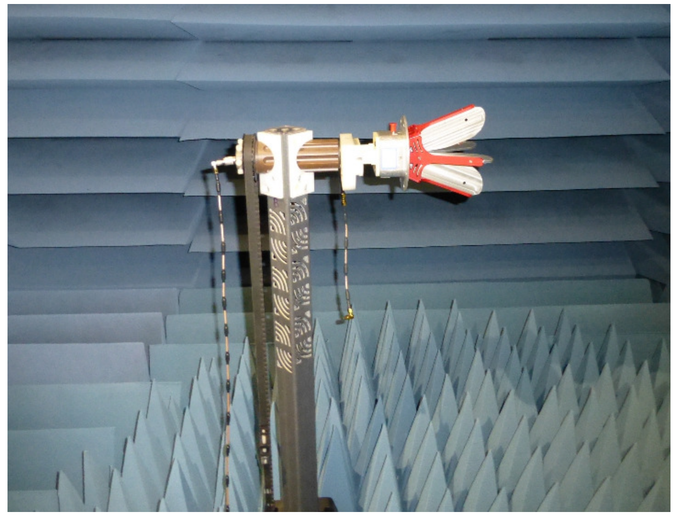

Figure 4. FDM-based Fixture for OTA Antenna Testing

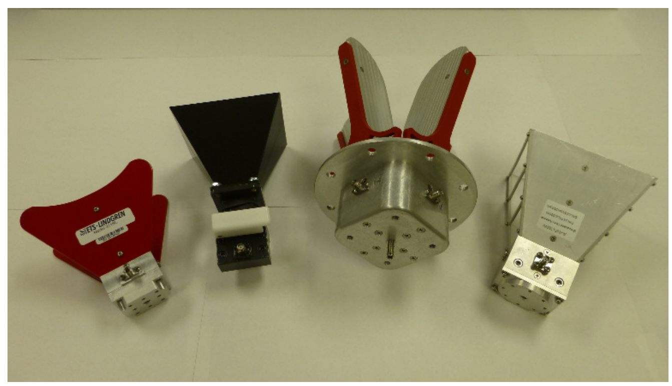

Figure 5. Four Different Frequency Calibrators Considered

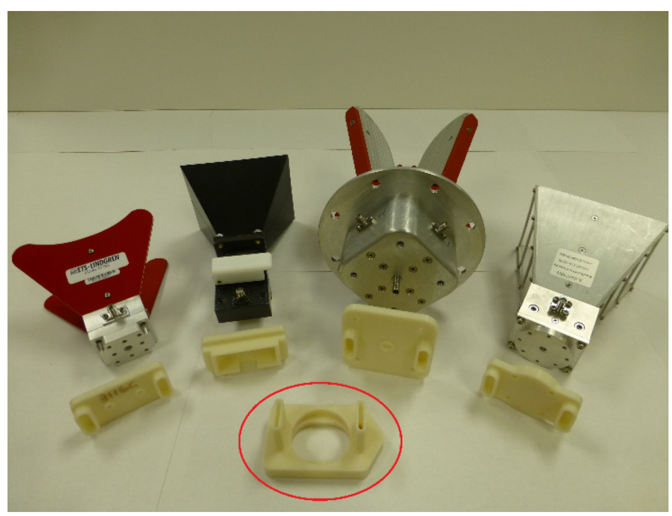

Figure 6. The Modular Fixturing System for Calibrators

The distance between two supporting arms of the main fixture was determined by the tail size of the calibrators. The thickness of the base plate for each fixture was estimated based on the weight of the calibrators, and the location of the screw holes on the modular fixtures was measured against the existing screw holes on the calibrator. The case was to test the mechanical properties of printed parts and to find out whether surface finish could be utilized in the part design.

The resulting fixturing system performed as expected. Since both the vertical and horizontal arms could rotate in increments of angles and stop for 5 to 10 seconds before the next rotation during the calibration process, the kinematic momentum was neglected. The setup time was drastically shortened, due to the ease of installation, and the rough surface finish from the layering process was incorporated into the design to provide necessary friction to hold the modular fixtures in position. There was no need to include threads, as the actual threads could be created by the screws during the attachment of the modular fixture to the calibrator. However, this design decision was made based on the type of screws used.

The shrinkage of material was much less significant when compared to the part's geometry and size. The imperfections from process variation could be easily overcome by post-printing manual filing and sanding; it is worth noting that these finishing processes had little to no impact on the part's structural integrity or positional accuracy, due to the planned clearance recommended by field practitioners. The overall time for part designing and testing was around eight hours; the printing time for individual fixtures ranged from 45 minutes to one hour. Only the main fixture went through a design revision, as it had to match the existing system. The design of modular fixtures was less time-consuming; once the concept had been proved to work, the following design became straightforward.

Legality of Reverse Engineering

While these two cases show the potential of using FDM parts for product sustaining actions, the industry is still advised to take careful yet practical measures in terms of intellectual property. As discussed previously, to create a functional part for purposes of product sustaining, whether it is a replica to replace the original part or an ad hoc part to expand or upgrade the product, the technique of reverse engineering is often used to obtain the needed dimensional information. Pooley [26] identifies six reasons for engaging reverse engineering: learning, changing or repairing a product, providing a related service, developing a compatible product, creating a clone of the product, and improving the product [27]. For information-based products from the software or semiconductor industries, reverse engineering could easily expose the core technology of the targeted products; therefore, such a practice is avoided as the current law prohibits [28]. Companies in these sectors tend to utilize known standards or release their application programming interfaces (APIs) to third-party partners in order to encourage development-compatible products. However, for traditional manufacturing industries, the main adaptor of 3D printing technology, reverse engineering "has always been a lawful way to acquire a trade secret, as long as the acquisition of the known product ... [is] by fair and honest means, such as purchase of the item on the open market." [29].

Nevertheless, the description of patents, trade secrets, or copyrights can be very broad, vague, or implicit, thereby leaving a lot of room for legal interpretation. The practitioners of reverse engineering should consult with the original equipment manufacturers as well as their legal counsel beforehand in order to obtain necessary consent or legal documentation prior to taking any action, even when the intended product or part may be obsolete, or the related patents may already be expired.

Conclusion

The approach to designing FDM parts to support post-sale lifecycle activities was examined in this study. The theories behind FDM and the field practitioners' suggestions were reviewed and put into the consideration of part design in the two cases presented. The author should point out that the use of a dial caliper to reverse engineer the parts was justifiable, since the parts created in these two cases did not require excellent precision. However, the trial-and-error approach in the first case did suggest the need for better measurement, preferably in CMM. While some trade magazines or vendors claimed "no manufacturing experience needed", the part designer could only create sound functional parts with the understanding of specific 3D printing processes, materials, and their limitations. In the end, both the design and manufacturing experiences were essential.

There were several technical breakthroughs, which field practitioners or even researchers should pay attention to. While powder-based SLS printing devices for metallic parts could be the next innovation driver [30], the development of polymer-based filaments with the addition of nano particles [31], or adhesives to bond 3D printing parts [32], could also expand the landscape of 3D printing applications. FDM printers with dual- or quad-heads had been commercially available; nevertheless, direct printing of composite materials through a single extruder head deserved more attention [33]. With the commercialization of these innovations, 3D printing could really be considered as the next "disruptive technology".

References

[1] Chang, Y. I., & Miller, C. L. (2005). PLM curriculum development: Using an industry-sponsored project to teach manufacturing simulation in a multidisciplinary environment. *Journal of Manufacturing Systems, 24*(3), 171–177.

[2] Manyika, J., Chui, M., Bughin, J., Dobbs, R., Bisson, P., & Marrs, A. (2014, February 11). Disruptive technologies: Advances that will transform life, business, and the global economy. McKinsey & Company. Retrieved February 11, 2014, from http://www.mckinsey.com/insights/business_technology/disruptive_technologies.

[3] Lipson, H., & Kurman, M. (2013). *Fabricated: The New World of 3D Printing*. John Wiley & Sons.

[4] Conley, J., & Marcus, H. (1997). Rapid prototyping and solid free form fabrication. *Journal of Manufacturing Science and Engineering, 119*, 811–816.

[5] Pham, D. T., & Gault, R. S. (1998). A comparison of rapid prototyping technologies. *International Journal of Machine Tools and Manufacture, 38*(10–11), 1257–1287.

[6] Levy, G. N., Schindel, R., & Kruth, J. P. (2003). Rapid manufacturing and rapid tooling with layer manufacturing (LM) technologies, state of the art and future perspectives. *CIRP Annals - Manufacturing Technology, 52*(2), 589–609.

[7] Hodgson, G. (2012, February 25). A History of RepRap Development. Retrieved from http://reprap.org/mediawiki/images/a/a5/A_History_of_RepRap_Development.pdf.

[8] Kulkarni, P., & Dutta, D. (1999). Deposition Strategies and Resulting Part Stiffnesses in Fused Deposition Modeling. *Journal of Manufacturing Science and Engineering, 121*(1), 93–103.

[9] Bellini, A., & Güçeri, S. (2003). Mechanical characterization of parts fabricated using fused deposition modeling. *Rapid Prototyping Journal, 9*(4), 252–264.

[10] Sood, A. K., Ohdar, R. K., & Mahapatra, S. S. (2010). Parametric appraisal of mechanical property of fused deposition modelling processed parts. *Materials & Design, 31*(1), 287–295.

[11] Lee, C. S., Kim, S. G., Kim, H. J., & Ahn, S. H. (2007). Measurement of anisotropic compressive strength of rapid prototyping parts. *Journal of Materials Processing Technology, 187–188*, 627–630.

[12] Croccolo, D., De Agostinis, M., & Olmi, G. (2013). Experimental characterization and analytical modelling of the mechanical behaviour of fused deposition processed parts made of ABS-M30. *Computational Materials Science, 79*, 506–518.

[13] Smith, W. C., & Dean, R. W. (2013). Structural characteristics of fused deposition modeling polycarbonate material. *Polymer Testing, 32*(8), 1306–1312.

[14] Masood, S. H., Rattanawong, W., & Iovenitti, P. (2003). A generic algorithm for a best part orientation system for complex parts in rapid prototyping. *Journal of Materials Processing Technology, 139*(1–3), 110–116.

[15] Thrimurthulu, K., Pandey, P. M., & Venkata Reddy, N. (2004). Optimum part deposition orientation in fused deposition modeling. *International Journal of Machine Tools and Manufacture, 44*(6), 585–594.

[16] Galantucci, L. M., Lavecchia, F., & Percoco, G. (2009). Experimental study aiming to enhance the surface finish of fused deposition modeled parts. *CIRP Annals - Manufacturing Technology, 58*(1), 189–192.

[17] Han, W., Danforth, S. C., Safari, A., & Jafari, M. A. (2002). Tool Path-Based Deposition Planning in Fused Deposition Processes. *Journal of Manufacturing Science and Engineering, 124*(2), 462–472.

[18] Ahn, D., Kweon, J.-H., Kwon, S., Song, J., & Lee, S. (2009). Representation of surface roughness in fused deposition modeling. *Journal of Materials Processing Technology, 209*(15–16), 5593–5600.

[19] Lee, K. H., & Woo, H. (2000). Direct integration of reverse engineering and rapid prototyping. *Computers & Industrial Engineering, 38*(1), 21–38.

[20] Zhongwei, Y. (2004). Direct integration of reverse engineering and rapid prototyping based on the properties of NURBS or B-spline. *Precision Engineering, 28*(3), 293–301.

[21] Bagci, E. (2009). Reverse engineering applications for recovery of broken or worn parts and re-manufacturing: Three case studies. *Advances in Engineering Software, 40*(6), 407–418.

[22] Designing mechanical parts for 3D printing - Shapeways. (2014, February 21). Shapeways.com. Retrieved February 21, 2014, from http://www.shapeways.com/tutorials/designing_mechanical_parts_for_3d_printing

[23] Designing Mechanical Parts - The Whoosh Machine - Shapeways. (2014, February 21). Shapeways.com. Retrieved February 21, 2014, from http://www.shapeways.com/tutorials/designing_mechanical_parts_3d_printing_the_whoosh

[24] Mechanical Design for 3D Printing - The Adventures of Eiki Martinson. (2014, February 21). Retrieved February 21, 2014, from http://eikimartinson.com/engineering/3dparts/

[25] Design rules and detail resolution for SLS 3D printing - Shapeways. (2014, February 21). Shapeways.com. Retrieved February 21, 2014, from http://www.shapeways.com/tutorials/design_rules_for_3d_printing.

[26] Pooley, J. (1999). Trade Secret Law, Sec. 5-18 and 5-19.

[27] Samuelson, P., & Scotchmer, S. (2002). The Law and Economics of Reverse Engineering. *The Yale Law Journal, 111*(7), 1575.

[28] Sullivan, J. D., & Morrow, T. M. (2003). Practicing Reverse Engineering in an Era of Growing Constraints under the Digital Millennium Copyright Act and Other Provisions. *Albany Law Journal of Science & Technology, 14*, 1.

[29] Act, U. T. S. (1990). Uniform Trade Secrets Act. *Uniform Laws Annotated, 14*, 433-467.

[30] Lewis, G. K., & Schlienger, E. (2000). Practical considerations and capabilities for laser assisted direct metal deposition. *Materials & Design, 21*(4), 417–423.

[31] Shofner, M. L., Lozano, K., Rodríguez-Macías, F. J., & Barrera, E. V. (2003). Nanofiber-reinforced polymers prepared by fused deposition modeling. *Journal of Applied Polymer Science, 89*(11), 3081–3090.

[32] Arenas, J. M., Alía, C., Blaya, F., & Sanz, A. (2012). Multi-criteria selection of structural adhesives to bond ABS parts obtained by rapid prototyping. *International Journal of Adhesion and Adhesives, 33*, 67–74.

[33] Nikzad, M., Masood, S. H., & Sbarski, I. (2011). Thermo-mechanical properties of a highly filled polymeric composites for Fused Deposition Modeling. *Materials & Design, 32*(6), 3448–3456.

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AN INITIAL LOOK AT ROBOTICS-BASED INITIATIVES TO ENGAGE GIRLS IN ENGINEERING

Jennifer G. Michaeli, Old Dominion University; Vukica Jovanovic, Old Dominion University;
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Abstract

Over the past 10 years, the use of robotic kits in K-12 Science, Technology, Engineering, and Math (STEM) initiatives as well as undergraduate engineering education has increased significantly. However, a survey of students in grades 9–12 indicated that only 2–3% of women in high school express an intention to study engineering; conversely, 16% of high school men declared that they plan to pursue an engineering degree [1]. In this paper, the authors present an initial review of published literature regarding the use of robotics in schools to identify cases where robotic kits have been used to engage girls in STEM learning and to discuss how robotics has been used or could be used to positively influence outcomes of girls' knowledge, interests, self-efficacy, and attitudes related to careers in engineering.

Introduction

A survey of students receiving STEM degrees in the U.S. shows that the numbers of technical degrees awarded to women and underrepresented minorities do not accurately reflect U.S. demographics. Based on the U.S. Census of 2010, women account for 50% of the total population and the workforce; however, they represent only 26% of the Science, Technology, Engineering, and Math (STEM) workforce. The total percentage of undergraduate engineering degrees awarded to women was 17.5% in 2008, while the percentage of bachelor's degrees in engineering technology awarded to women in 2011 was 9.5%. Based on statistics from the U.S. Department of Labor, only 11% of Aerospace Engineers and less than 6% of Mechanical Engineers are women [2]. Recent studies have indicated that girls are participating equally in middle and high school studies in science, mathematics, and technology; however, the number of female graduates of engineering programs as well as the number of female engineers in the workforce are still low [3-5].

As reported by McCrea [6], the percentage of U.S. girls interested in STEM careers has not improved in comparison to statistics from 10 to 20 years ago. Furthermore, the number of middle-school-aged girls who reported an interest in STEM subject areas by the time they are graduating high school and entering college have drastically declined, indicating that even in the middle to high school years, female student retention in STEM is not being properly addressed. These are alarming trends and represent a complex problem that will have a dramatic impact on the U.S. workforce and economy.

Factors Influencing Women in Engineering

Female high school students do not choose to pursue engineering as their career paths for various reasons, many of which are related to their perception of engineering [7]. One of the widespread perceptions is that engineering is viewed as a predominately male field [8]. Additionally, there is a perception that engineering has fewer opportunities for creative development [9]. A 2-year study of 403 students attending community college used a 28-item "perceived chilly climate scale" as a metric to assess the environment for learning and found that an environment that is perceived as "chilly" puts women at an educational disadvantage and many of them decide not to enroll or end up switching majors [10]. These perceptions have been documented in studies on females from elementary school through graduate studies and even through employment [5]. A study funded by the National Science Foundation (NSF) and conducted at the University of Wisconsin-Milwaukee in 2011 surveyed 3700 female engineers and reported that one-third responded that they did not enter engineering after graduation because of their perception of engineering being inflexible or the workplace culture being non-supportive of women [11]. Some researchers suggest that this perception of gender and STEM occurs very early on in life if parents treat their children differently according to their gender and with the choice of toys that children are exposed to for playtime [12].

Women who do pursue careers in STEM fields typically choose careers that have traditionally had higher concentrations of women, such as fields related to health, education, and the social and behavioral sciences [13]. This trend continues even though much higher salaries can be earned by pursuing careers in information technology and engineering. One reason for this seems to be that these fields are male-dominated and women who pursue these careers may be perceived as, or even perceive themselves as, more masculine [10]. Furthermore, women have reported that they do not feel welcome in college majors and career fields that typically have higher concentrations of men, such as engineering and engineering technology. This relates to the need for a sense of community that is important to women [10]. An ethnographic study of engineering courses reported that women encountered negative behavior from male students [14], [15]. As a result, women may feel compelled to avoid college majors that are traditionally male-dominated in order to avoid these unwelcoming and negative attitudes.

Gender perceptions and masculinity are not the only obstacles to engaging female students to consider engineering careers. A study in 2005 regarding female student interest in pursuing electrical engineering suggests that the dominant factor for the female pupils when considering the academic field of study is not the masculine image of the profession, but rather the level of familiarity with the domain and actual interest in the field [16].

Another factor influencing our young women is the lack of female role models who encourage students to pursue STEM careers. McCrae points out the need for more female -led STEM groups that can attract more girls to technical careers and retain female students who express an interest in middle school but seem to fall off course in high school. McCrae [6] concludes that "an after-school math or science club that's headed up and championed by a female teacher, …, can go a long way in getting girls to consider STEM degrees and careers". He also points to the need to include more hands-on learning opportunities for students to understand how education connects to future careers. For example, robotics labs can help students identify with a career in engineering. Coupling hands-on learning with female-led initiatives could lead to the attraction and retention of girls in engineering careers.

Methods to Engage Women in Engineering

Universities across the country have started programs such as Women in Engineering to focus on reaching out to high school female students. These programs have resulted in more women enrolled in engineering programs in regional areas [16-18]. These programs use different vehicles for recruitment such as newsletters, websites, face-to-face interaction with program leadership, youth expos, summer workshops [18], peer mentoring, scholarships, visits to schools, one-day conferences [16], and camps. The reason for these various outreach methods is that different women's groups do not respond the same way to any given recruiting method. Although high school students who have better knowledge about engineering were much more likely to report aspirations for studying engineering in college, there is still a gap when it comes to the girls having engineering college aspirations, even when moderated by recruitment [14].

According to White and Wasburn [5] various online recruiting materials have been developed specifically for female audiences and include showcasing successful women in STEM careers. More than two-thirds of online projects reviewed by White and Wasburn focused on technology to increase student engagement, and one-third included goals of career awareness or gender equity awareness. The researchers identified four factors that online activities should incorporate in order to successfully overcome gender-specific issues in career selections: 1) Career Information and Exploration; 2) Personal Identification and Relevance; 3) Real-world Application and Context; and, 4) Social Interaction and Teamwork.

Several studies have reported the effect of mentorship and role models on the future career choices of middle school and high school students, especially in STEM education [6], [19]. A study by Abrams and Fentiman [17] concluded that focusing only on recruiting efforts cannot increase the percentage of women in engineering. Efforts to successfully engage women in engineering must also assist women in the development of a supportive, sustainable network that will increase their chances of successfully completing an engineering degree.

Some studies suggested that one way of attracting women to engineering could be showcasing engineering as more creative and more receptive to female students. One approach to achieve this is to engage girls in cooperative team projects [20], [21]. However, research suggests that teachers are not adequately prepared to address gender-equity concerns in their classrooms [22].

A wide range of K-12 programs across the country are using robotics as a very engaging tool for education, including competitions that challenge students at different levels [8]. Girls do participate in many of these robotic contests as valuable team members and enjoy building and programming robots. However, the effect of these different efforts on engaging the female population in STEM careers has not been well documented.

Robotic Kits in K-12 STEM

Over the past 10 years, the use of robotic kits in K-12 STEM initiatives as well as undergraduate engineering education has increased significantly. This phenomenon has been motivated by many factors including the diversity of inexpensive robotic kits and their ease of assembly and programming, as well as documented research that hands-on, project-based learning initiatives provide ways to engage students that traditional learning—including lectures and assignments, as well as advanced methods such as simulations and gaming—cannot.

Robotic kits provide opportunities to help highlight practical elements of the curriculum that can be more easily demonstrated and retained through hands-on learning and can make STEM learning more accessible for all students including female students, underrepresented minorities, and students with disabilities [23]. However, a recent survey [8] about the use of robotics to engage students showed that many educational efforts were primarily focused on using robots to teach robotics, without a broader sense of engineering and career opportunities. Additionally, few studies have been conducted on how robotics can be properly utilized in education in order to engage girls and other underrepresented groups towards engineering.

Robotics is multidisciplinary in nature and fully integrates many engineering subjects. Weinberg et al. [24] presented a model for multidisciplinary cooperation that included various engineering disciplines and computer science, which elevates robotics to a potentially pivotal position in engineering education. As part of their research, they formed a collaborative working group, which they called the Multidisciplinary Project Action Group (MPAG), as a way to bring together faculty members from the engineering and computer science departments who share a common desire to develop and deliver effective, multi-disciplinary learning activities for students in their respective college majors.

Mataric et al. [25] and his colleagues developed an affordable robotic platform and a free, public-domain robot programming workbook. Their intent was to make concepts related to robotics more accessible to educators and students at all levels. These free, detailed resources are valuable for removing barriers of entry for students and educators at the K-12 and university level and to provide direct access to hands-on learning about robotics. These types of robotic kits and resources could be utilized to engage girls in learning about engineering majors and careers.

Thomaz et al. [26] studied children in Brazil and presented an overview of the learning process of children who have been denied access to technology in education, referred to as “digitally excluded”, and how educational robots can benefit these children. Their work, referred to as the “digital inclusion project”, showed very positive results on impacting student learning and introduction of new technologies when children have little to no prior contact with technologies were introduced to educational robots. The results indicated that this project improved the educators’ skills by supporting teaching techniques in the classroom when using the robot as an interdisciplinary tool to address subjects such as Portuguese, Mathematics, Art, and Geography. The study did not specifically target girls, but highlighted how educational robots can have a positive impact on underrepresented students.

A novel study by researchers Lu and Mead [27] presented how a new generation of students perceives human-robot interaction (HRI) and its potential impacts on society. The focus of the study was to teach students how to program robots to express emotion and intent only through the robot's physical actions. The authors believed that exposure to sociable robotics would have the potential to increase interest in STEM-related activities, particularly for girls.

Another recent study [28] focused on the VEX Robotics competition, an international program for middle and high school students, with the same goal of engaging students in the study of STEM; this time, though, through a competition, where students build robots to solve a challenge. Survey data from 341 students and 345 coaches indicated that 94% of coaches reported increased interest in science and technology and 50% reported increased interest in math and science classes as a result of robotics-based competitions. The study even looked at students from different academic levels, and showed that the robotic competition was beneficial for all of them. That is, about 20% of students with high GPAs, and would have pursued a STEM-related college major, even without the robotic competition exposure, reported a change of interest from pure science majors to engineering-based college majors. On the other hand, students with lower GPAs, who were struggling in math classes, reported that participation in robotics competitions encouraged them to study auto/machine-tool technology or electronics, for example, and motivated them to do better in school. Approximately 30% of the participants in the study were female.

A different approach to analyzing the benefits of robotics curricula was presented by KcKay et al. [29]. That study compared formal (classroom setting) and informal (summer camps) learning environments in order to understand the impact of robotics curricula on student learning of science concepts and their awareness and interest in engineering careers. This study of 440 students across four learning sites (two formal and two informal) showed that students in the informal environment did better on content learning than students in formal classroom settings, and they also did better on STEM interest and engagement. The study suggested that the overall better results with the informal sites may be due to the amount of time spent on the curriculum during the intensive one-week summer camp experience. Approximately 50% of the students were female. The results of the study did not specifically link to the gender of the participants and reported that gender was not a factor when comparing formal to informal setting results.

The research by Takaghaj et al. [30] involved a mentor-supported robotics project. The program used Lego Mindstorms NXT and consisted of an unstructured design project geared for a robotic competition. In addition, girls were supervised in their own schools by a female engineer serving as a mentor. The survey considered both girls-only schools and classrooms with boys and girls in equal numbers. The study showed that this set up was successful in stimulating girls' interest toward STEM careers. As this was a relatively recent study, and the students involved in the survey were basically children that grew up in a highly technological era, the paper mentioned that the girls started the program already knowledgeable about engineering or robotics and had positive images of engineering. Still, the survey results indicated that the program was successful in improving attitudes even further.

Although the actual number has not been reported, the majority of U.S. engineering schools include team-based student competitions in their undergraduate programs. One such example is the VEX Robotics competition, which includes 3500 teams from 20 countries annually [28]. Some of these competitions even feature all-female teams such as the ones for SAE Mini-Baja competition [8]. Qualitative feedback from these events obtained from after-project surveys showed a positive impact on retaining women enrolled in engineering programs. Based on the literature survey presented here, these findings can be attributed to the hands-on aspect of these competitions and the mentoring and community support that comes with a team comprised of all females.

Conclusions

In conclusion, women are grossly underrepresented in the STEM workforce, especially in engineering and engineering technology. The number of girls in grades 9–12 who have indicated their intentions to pursue engineering is significantly less than their male counterparts. There are numerous factors that have been linked to the low numbers of women in engineering as well as the low number of girls interested in pursuing technical careers, notably the "perceived chilly climate" and lack of female mentors and role models. While the use of robotic kits in K-12 STEM education has increased significantly in the last five years, studies carried out on the use of robotics to engage students focused primarily on using robots to teach robotics, without a broader sense of engineering and career opportunities. Furthermore, few studies have shown the use of robotics to engage female students in STEM, or engineering in particular, and these studies lacked any formal evaluation or assessment. Thus, there is no clear evidence in the literature on whether robotics can effectively engage girls in engineering.

Based on the outcome of this literature survey, the authors intend to collaborate and explore the use of robotics as a hands-on learning tool to effectively engage girls and excite them about the study of engineering and engineering technology and career opportunities in these fields. This proposed study plan will incorporate key findings from this literature survey on how to engage girls in STEM, including the need for female mentoring and female role models, the need for a sense of community and inclusion, the need to overcome the "perceived chilly climate", and the need to feel part of a "greater good". The partnership of Old Dominion University (ODU) and Wayne State University (WSU) brings together two higher education institutions with the infrastructure, assets, capabilities, and expertise necessary to carry out this research through existing cooperative agreements with high schools in Hampton Roads and Detroit Metro Area public school districts.

References

[1] Cordova-Wentling, R., & Camacho, C. (2006, June 18 -21). *Women Engineers: Factors and Obstacles Related to the Pursuit of a Degree in Engineering.* Paper presented at the ASEE National Conference, Chicago, Illinois.

[2] White, D., Steinhauer, H., & Davids, L. (2006, October 9-12). *A Hands-on Approach to Increasing Engineering Diversity: ERAU's All-Women Mini-Baja Project.* Paper presented at the 5th Annual ASEE Global Colloquium on Engineering Education, Rio de Janeiro, Brazil.

[3] Clewell, B. C., & Campbell, P. B. (2002). Taking stock: Where we've been, where we are, where we're going. *Journal of Women and Minorities in Science and Engineering, 8*(3/4), 255-284.

[4] Freeman, C. E. (2004). Trends in educational equity of girls & women: 2004. *National Center for Education Statistics*. Washington, DC: U.S. Government Printing Office: U.S. Department of Education.

[5] White, K., & Wasburn, M. (2006, June 18-21). *A Protocol for Evaluating Web-Based Resources to Interest Girls in Stem Careers.* Paper presented at the ASEE National Conference, Chicago, Illinois.

[6] McCrea, B. (2010). Engaging Girls in STEM. *T.H.E Journal Magazine*.

[7] Jayaram, U. (1997). *Increasing Participation of Women in the Engineering Curriculum*. Paper presented at the ASEE/IEEE Frontiers in Engineering Conference.
[8] Benitti, F. B. V. (2012). Exploring the Educational Potential of Robotics in Schools: A Systematic Review. *Computers & Education, 58*(3), 978-988.
[9] Hamid, N. A., Radzi, S. A., Noh, Z. M., & Ibrahim, M. (2009, December 7-8). *Tendency of women in engineering program offered by UTeM.* Paper presented at the International Conference on Engineering Education (ICEED), Kuala Lumpur, Malaysia.
[10] Morris, LaDonna K., & Daniel, Larry G. (2008). Perceptions of a Chilly Climate: Differences in Traditional and Non-traditional Majors for Women. *Research in Higher Education, 49*(3), 256-273. doi: 10.1007/s11162-007-9078-z.
[11] Fouad, N., & Singh, R. (2011). *Stemming the Tide: Why Women Leave Engineering*. A study funded by NSF and conducted at University of Wisconsin-Milwaukee.
[12] Mammes, I. (2004). Promoting Girls' Interest in Technology through Technology Education: A Research Study. *International Journal of Technology & Design Education, 14*(2), 89-100.
[13] Lanzer, F. (2009, September 16-18). *Attracting Girls to Engineering & Technology: Reach them before they're turned off.* Paper presented at the Mid-Atlantic Section Conference of the American Society for Engineering Education, Lincoln, NE.
[14] Porche, M., McKamey, C., & Wong, P. (2009, June 14-17). *Positive Influences of Education and Recruitment on Aspirations of High School Girls to Study Engineering in College.* Paper presented at the ASEE National Conference, Austin, Texas.
[15] Tonso, K. L. (1998). *Engineering gender--gendering engineering: What about women in nerd-dom?* Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA.
[16] Hazzan, O., Levy, D., & Tal, A. (2005). Electricity in the palms of her hands--the perception of electrical engineering by outstanding female high school pupils. (Author Abstract). *IEEE Transactions on Education, 48*(3), 402.
[17] Bottomley, L., Titus-Becker, K., & Smolensky-Lewis, H. (2009, June 14-17). *Escape to Engineering: A Summer Bridge Program for Women in Engineering.* Paper presented at the ASEE Annual Conference, Austin, Texas.
[18] Abrams, L., & Fentiman, A. W. (2002, June 16-19). *An Integrated Program to Recruit and Retain Women Engineering Students*. Paper presented at the ASEE National Conference, Montreal, Canada.
[19] Liston, C., Peterson, K., & Ragan, V. (2008). *Evaluating Promising Practices in Informal Science, Technology, Engineering, and Mathematics (STEM) Education for Girls*. (E. R. Associates, Trans.): Girl Scouts of America, Motorola Foundation.
[20] Springer, L., Stanne, M., & Donovan, S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *The College Mathematics Journal.*
[21] Terenzini, P. T., Cabrera, A. F., Colbeck, C. L., Parente, J. M., & Bjorklund, S. A. (2001). Collaborative Learning vs. Lecture/Discussion: Students' Reported Learning Gains*. *Journal of Engineering Education, 90*(1), 123-130. doi: 10.1002/j.2168-9830.2001.tb00579.
[22] Whyte, H. (1992). Female Friendly Science: Applying Women's Studies Methods and Theories to Attract Students. *Feminist Teacher* (1), 40.
[23] Cooper, M., Keating, D., Harwin, W., & Dautenhahn, K. (1999). *Robots in the classroom - tools for accessible education*. Paper presented at the 5th European Conference for the Advancement of Assistive Technology (AAATE), Düsseldorf, Germany.
[24] Weinberg, J. B., Engel, G. L., Gu, K., Karacal, C. S., Smith, S. R. , White, W. W., et al. (2001). *A Multidisciplinary Model for Using Robotics in Engineering Education*. Paper presented at the ASEE Annual Conference & Exposition, Edwardsville, IN.
[25] Mataric, M. J., Koenig, N., & Feil-Seifer, D. (2007). *Materials for Enabling Hands-On Robotics and STEM Education. American Association for Artificial Intelligence*. Paper presented at the AAAI Spring Symposium on Robots and Robot Venues: Resources for AI Education.
[26] Thomaz, S., Aglaé, A., Fernandes, C., Pitta, R., Azevedo, S., Burlamaqui, A., et al. (2009). *RoboEduc: A Pedagogical Tool to support Educational Robotics*. Paper presented at the 39th ASEE/IEEE Frontiers in Education Conference, San Antonio, TX.
[27] Lu, D. V., & Mead, R. (2012). *Introducing Students Grades 6-12 to Expressive Robotics*. Paper presented at the HRI 2012 Video Session, USA 411, Boston, MA.
[28] Hendricks, C., Alemdar, M., & Williams-Ogletree, T. (2012, June 26-29). *The Impact of Participation in VEX Robotics Competition on Middle and High School Students' Interest in Pursuing STEM Studies and STEM-related Careers.* Paper presented at the ASEE National Conference, Vancouver, B.C., Canada.
[29] McKay, M. M., Lowes, S., Tirthali, D., Sayers, J., & Peterson, K. A. (2013). *Transforming a Middle and High School Robotics Curriculum.* Paper presented at the ASEE National Conference, Atlanta, Georgia.
[30] Takaghaj, S. M., Macnab, C., & Friesen, S. (2011,

June 26-29). *Inspiring Girls to Pursue Careers in STEM with a Mentor-Supported Robotics Project.* Paper presented at the ASEE National Conference, Vancouver, B.C., Canada.

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ANA DJURIC received the Dipl.-Ing. Degree in mechanical engineering from the University of Belgrade, Serbia, focusing on Control Systems; the M.A.Sc. degree in Industrial and Manufacturing Systems Engineering from the University of Windsor, Canada, in the area of Industrial Robotics; and a Ph.D. degree in Mechanical Engineering from the University of Windsor, Canada, in the area of Reconfigurable Robotics. Prior to her arrival at WSU, Dr. Djuric worked in industry for five years. She worked as a machine and tool designer first and then as a Robotics software Analyst. Dr. Djuric worked as an instructor for four years at the Mechanical, Automotive, and Materials Engineering, and Industrial and Manufacturing and Systems Engineering departments at the University of Windsor. Since the fall of 2011, she has been an Assistant Professor of Engineering Technology in the College of Engineering at Wayne State University. Dr. Djuric is working on undergraduate and graduate research and she is a member of the Council on Undergraduate Research (CUR). Dr. Djuric's research areas include Industrial robots, kinematics, dynamics, control, and advanced manufacturing systems. She has published over 40 journal and conference papers.

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Process Capability in a Computer-integrated Manufacturing Cell

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Abstract

As globalization expands and new technology spreads, companies look for different ways to expand their businesses through the use of new innovative technologies. One way that companies are remaining competitive is through the use of automation in their manufacturing processes. With increased automation, companies have the potential to improve upon one key business metric: increased production. Companies are experiencing increased production because automation has the ability to save time and reduce scrap/rework. The one downfall of the implementation of automation is that most companies fail to fully integrate the automation into the entire system. Instead, the automation functions as an island in the manufacturing process that can lead to problems such as bottlenecks and inefficient work flow. Since the automation is not fully integrated, the company will be unable to reach the full potential of its automated equipment. One way to combat islands of automation is through the use of Computer Integrated Manufacturing (CIM). A CIM cell allows the integration of automation into the entire manufacturing process, from ordering raw materials to the production of final goods.

Introduction

Garbage-In-Garbage-Out, not always! This study attempted to determine if the integration of the Renishaw spindle probe functioning as an in-process measuring device had the ability to eliminate variation in a CIM cell. If variation is eliminated through the use of the in-process measuring device, then this presents the opportunity for improving final process capability. With the rise of automation in traditional manufacturing processes, more companies are beginning to integrate computer integrated manufacturing (CIM) cells on their production floors. Process integration eliminates broken processes and is crucial to optimizing the manufacturing environment [1]. By fully integrating the automation, the company has the potential to further improve production and remain competitive [2]. CIM has increased in popularity as companies begin to realize the full potential CIM cells have to offer. Along with seeing the benefits CIM cells have to offer, the increase in user-friendly technology has also increased the prominence of integrated systems. These integrated systems allow companies to use computer operating systems to control manufacturing processes. One specific example is computer-aided design (CAD), computer-aided manufacturing (CAM), and Supervisory Control and Data Acquisition (SCADA) software that has become a vital part of integrating Computer Numerical Control (CNC) machining centers into CIM cells. These three software packages have increased user friendliness, making CNC integration a practical approach for businesses both small and large. Overall, improved integration software will allow more companies to use CIM cells during their manufacturing processes [1].

Through CIM cell integration, companies have the ability to reduce process time and increase production. One of the problems created with CIM cell automation is caused by the dependency the sequential steps have on one another. Dependency created by the previous step increases the probability that a process error could occur due to previous variation. This compounding variation can cause the entire process to become inefficient. One way to eliminate this dependency is through the use of an in-process measuring device such as a Renishaw spindle probe used in conjunction with a CNC milling machine.

Western Kentucky University (WKU) utilizes a CIM cell in the Senator Mitch McConnell Advanced Manufacturing and Robotics laboratory. The laboratory is located in the Architectural and Manufacturing Sciences department and gives students the opportunity to learn how automated systems can be integrated. The CIM cell consists of three Mitsubishi six-axis robots, a Haas Mini-Mill, a Haas GT-10 lathe, an AXYZ, Inc. CNC router table, an Epilog 120-watt laser engraver, an Automated Storage and Retrieval System (ASRS), material handling conveyor, and vision station. The CIM cell functions throughout the curriculum as a means for applied learning and research. The authors used this CIM cell in order to determine if an in-process measuring device, such as the Renishaw spindle probe, had the ability to affect process capability.

The authors conducted a case study to determine the changes in process capability. If variation is eliminated through the use of the in-process measuring device then this presents the opportunity for improving final process capability. The ability to eliminate variation with the use of an in-process measuring device had the potential to shed new light on the topic of process capability in a CIM cell. Conventional teaching says that increasing final process capability over initial process capability is not possible (Garbage-In-Good-Out), due to the increased variation that each step in the process introduces. Since the entire process consisted of automated process execution, errors such as misaligned part placement had a direct effect on the next step. Each time increased variation occurs process capability suffers. Process capability is determined by the previous steps of the process [3]. The information gained from this process capability study has the potential to change the traditional definition of process capability. The knowledge gained on process capability will be useful to companies that have integrated CNC machining centers into their CIM cells.

Hypothesis

$H_0$1: There was no difference between initial process capability and final process capability without the use of the in-process measuring device.

$H_1$1: There was a difference between initial process capability and final process capability without the use of the in-process measuring device.

$H_0$2: There was no difference between initial process capability and final process capability with the use of the in-process measuring device.

$H_1$2: There was a difference between initial process capability and final process capability with the use of the in-process measuring device.

$H_0$3: There was no difference between final process capability with the in-process measuring device and final process capability without the in-process measuring device.

$H_1$3: There was a difference between final process capability with the in-process measuring device and final process capability without the in-process measuring device.

By increasing process capability, the company has the potential to reduce scrap and rework that will save time and increase profits. The Renishaw spindle probe has the potential to save time when integrated into a CIM cell, even though using the probe adds an extra step in the process. Time can be saved by preventing extra work from being dedicated to scrapping parts or investing time into reworking the work piece. The amount of time the probe can save increases with the increased complexity of the manufactured part, due to the longer machine time invested in the component. Some parts can take several hours to machine from raw material to final product, making it crucial to prevent scrapping of parts as a large amount of time has been invested into the machining process. Improving process capability is a vital part of Six Sigma, so improving process capability in a CIM cell will also be beneficial to companies trying to increase their Sigma level. Reaching Six Sigma requires reducing defects to 3.4 defects per million opportunities. There are two ways to decrease the number of defects in a process: the company can extend the upper and/or lower control limit or the company can improve the process capability [3].

Methodology

Before the aluminum blocks were processed in the CIM cell, they were manufactured to the desired size of 130 mm X 130 mm. Aluminum flat stock measuring 152 mm wide by 3658 mm long and 19mm thick was used to make the 100 aluminum blanks. Machining the blocks to the desired size was handled by using the following equipment: a horizontal bandsaw (see Figure 1), a waterjet, and three vertical milling machines. The first step conducted on the aluminum flat stock was to cut the 3658 mm sticks into 1220 mm sections using the horizontal bandsaw to help with the handling of the raw material.

Figure 1. Horizontal Bandsaw used to Cut Aluminum Flat Stock

Once the sticks were cut into 1220 mm sections, they were then placed on the waterjet table to cut the overall width of the material to around 135 mm. Removing excess material from the width decreased the amount of time spent on the milling machine. After all of the 1220 mm sections were processed on the waterjet, the material was taken back to the bandsaw and cut into sections of around 135 mm. This allowed the authors to get nine aluminum blanks out of each 1220 mm stick. With the blanks now measuring roughly 135 mm X 135 mm, the final machining was handled by the three manual milling machines. Due to the way the aluminum blocks were processed, one factory edge was present on all of the blocks. This factory edge was then used as a positive stop during the machining process on the mill (see Figure 2). The aluminum blocks were placed vertically in the vise with the factory edge against the base of the vise.

Figure 2. Aluminum Block with Factory Edge Against the Base of Vise

A positive stop was placed in the Z axis allowing the operator to take several passes on the aluminum blank until it reached the final dimension of 130 mm. With the X dimension within the desired specification, the Y dimension was processed next. The part was then clamped in the vise with the jaws applying pressure to the two parallel X sides (see Figure 3). One of the Y sides was then machined perpendicular to the X axis to true up the edge.

Figure 3. Clamping Position to Machine First Y Axis

With three sides processed, the fourth side was machined in the mill to bring the Y axis to its final specification. The block was then placed vertically in the vise with the previously processed Y axis resting against the base of the vise (see Figure 4).

Figure 4. Processing Final Y Axis with Aluminum Block Placed Vertically in Vise

A positive stop used in the Z axis allowed the operator to machine the block to 130 mm in the Y axis.

For this study, the authors used the 130 mm X 130 mm aluminum blocks in the CIM cell. A photo of the CIM cell (see Figure 5) shows a general view of the cell layout. One side of the aluminum blocks were processed with the use of the Renishaw spindle probe; the other side without the Renishaw spindle probe.

Figure 5. CIM Cell Layout

In order to run the blocks, the ASRS was loaded with the 100 aluminum blocks and processed in the CIM cell without the use of the Renishaw spindle probe. Due to the holding capacity of the ASRS, the ASRS was loaded in sets in order to run all 100 blocks. The process started with the ASRS robot picking up the pallet on which the aluminum block was resting, and moving the pallet to a buffering station. Once the aluminum block was loaded onto the buffer station, the Mitsubishi robot moved into position to grab the aluminum block from the pallet. The Mitsubishi robot used a set of grippers to grab the aluminum block from the pallet. Once the Mitsubishi robot had the part, the robot moved down a linear slide to place the aluminum block in the Haas Mini-Mill CNC vise (see Figure 6). The Haas Mill used a 6.35 mm HSS four-fluted end mill to machine a square pocket in the center of the aluminum blocks. The pocket was 7 mm deep and measured 25 mm in the X dimension and 25 mm in the Y dimension. The CNC was programmed to move to the center of the aluminum block 65 mm in the –X axis and 65 mm in the +Y axis from the top left corner of the part. The top left corner of the part was programmed from the top left corner of the CNC vise. The tool bit was swapped out after 25 blocks were processed, or whenever excessive tool wear occurred.

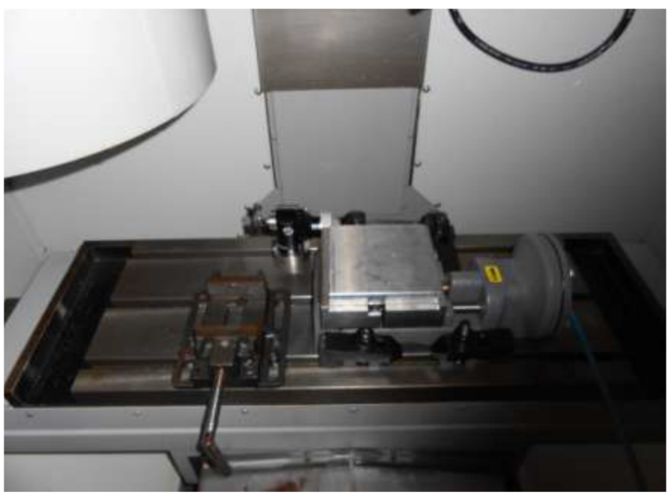

Figure 6. Aluminum Block Clamped in CNC Vise

When a new bit was loaded into the CNC machine, it was set up using the Renishaw tool touch off setter. After the square pocket was milled into the aluminum block, the Mitsubishi robot moved back into position to grab the aluminum block. The Mitsubishi robot secured the aluminum block by closing the grippers around the part. Once the grippers were closed on the aluminum block, the CNC vise opened and the Mitsubishi robot moved to place the aluminum block back on the pallet located at the buffer station. With the aluminum block loaded on the pallet located at the buffer station, the ASRS robot moved into position to pick up the pallet and placed the pallet back on the ASRS. The process repeated until the 100 aluminum blocks were machined. Once the blocks were machined, final process capability was recorded.

With the CIM cell process described, the problem with process capability became prominent. The previously stated variation was not a comprehensive list of every form of variation that the CIM cell introduced, but the amount of variation covered showed how each process added to an automated process introduced new variation and decreased process capability [4]. The authors defined the problem in the study to encompass process capability in a CIM cell. Process capability was defined as the problem because, in a CIM cell, initial process capability of the work piece affects the final process capability of the work piece. A direct effect is created by initial process capability because each step is dependent on the previous. The dependency created causes each step to introduce more variation into the process. Increased variation causes final process capability to decrease, preventing the final process capability from exceeding initial process capability. Decreased process capability caused by increased variation can be detrimental to the final product, causing the product to fall outside the upper or lower specification limits established by the customer. The study planned to combat the problem of increased variation through the use of an in-process measuring device. The measuring device, a Renishaw 40-2 CNC spindle probe (see Figure 7), was used to measure the exact coordinate positioning of a part in the CNC vise.

Figure 7. Renishaw 40-2 Spindle Probe

Instead of programming the center of the aluminum block off of the top right corner of the vise, the authors used the spindle probe to measure the true center of the aluminum block. The true center of the aluminum block was found by measuring the distance between the four sides of the aluminum block with the Renishaw spindle probe. The Renishaw spindle probe touched X1 and X2 then measured the length and divided this measurement by two. The probe then did the same thing for the two Y sides of the aluminum block. By measuring the exact coordinate positioning and finding the true center of the aluminum block, previous variation caused by positioning error and variation in initial size of the aluminum blocks was eliminated. Along with the integration of the probe, the tool was also monitored before machining each block by measuring the tool wear with a Renishaw tool touch off setter. The authors used the Renishaw spindle probe to determine the ability to increase final process capability over initial process capability and increase final process capability over the group of aluminum blocks processed in the CIM cell without the use of the probe.

In order to measure and gather the six sets of data used in the study, the authors used a Mitutoyo caliper to measure the X and Y dimensions. The Mitutoyo caliper could measure to one hundredth of a millimeter and was used in conjunction with MeasurLink Real Time Plus. MeasurLink Real Time Plus is a measuring computer software that was directly wired to a Mitutoyo caliper with a communication cable. The software allowed the Mitutoyo caliper to transfer measurements from the caliper to the computer with the push of a foot pedal. By using the MeasurLink software linked with the Mitutoyo caliper, user error by manually writing in the numbers was eliminated.

The initial process capability was calculated by using the measurements gathered in regards to the X and Y dimensions of the 100 aluminum blocks. Equation (1) was used to calculate the C_p for the aluminum blocks established by the manufacturer in both the X and Y dimensions. A C_{pk} was also calculated for the aluminum blocks supplied by the manufacturer using Equations (2)–(4) in both the X and Y dimensions [5].

$$C_p = (USL - LSL)/ 6\sigma \tag{1}$$

$$C_{pk} = (1 - K) \times C_p \tag{2}$$

$$K = 2\,|\mu - M| / (USL - LSL) \tag{3}$$

$$M = (USL + LSL)/2 \tag{4}$$

where,
K = capability index
M = midpoint
μ = process mean
σ = standard deviation
USL = Upper Specification Limit
LSL = Lower Specification Limit

The final process capability with the in-process measuring device and the final process capability without the in-process measuring device were calculated using Equations (1)–(4). The only difference was how the process capability was measured in regards to the X and Y dimensions used to calculate the process capability. The final capability measure was based on how close the square pocket was milled into the center of the aluminum block in both the X and Y dimensions. The authors took X1-X2 and Y1-Y2 measurements which were centered on the nominal value of 0 mm. The C_p and C_{pk} values were used to determine if the Renishaw spindle probe had a direct effect on process capability in the study when analyzed in regards to: initial process capability X, initial process capability Y, final process capability without in-process measuring device X, final process capability without in-process measuring device Y, final process capability with in-process measuring device X, and final process capability with in-process measuring device Y.

Findings

After all of the data were collected using the MeasurLink software, the data were transferred to Microsoft Excel in order to determine the process capability for the various parameters measured in this study. Descriptive statistics were calculated for the six sets of 100 data points (initial process capability X, initial process capability Y, final process capability without in-process measuring device X, final process capability without in-process measuring device Y, final process capability with in-process measuring device X, and final process capability with in-process measuring device Y). These descriptive statistics were then used to calculate C_p and C_{pk} using the equations mentioned above (see Table 1).

Table 1. Process Capability Data for Six Sets of Data

	X - C_p	X - C_{pk}	Y-C_p	Y - C_{pk}
Initial Process	7.19	7.16	2.75	2.70
Final Without Probe	0.62	0.56	1.48	0.96
Final With Probe	3.94	3.52	3.84	3.01

After gathering the results from this study, the authors were able to come to a conclusion about the previously stated hypotheses. Based on the C_p and C_{pk} results, the authors were able to accept the first research hypothesis:

$H_1$1: There was a difference between initial process capability and final process capability without the use of the in-process measuring device.

The first research hypothesis was accepted based on the change that occurred in the process capability from the initial capability to the final capability without the use of the in-process measuring device. When the in-process measuring device was not in use, the added variation introduced by the CIM cell caused the process capability of the work piece to decrease (see Table 1). The data collected also revealed that the authors could retain the second research hypothesis:

$H_1$2: There was a difference between initial process capability and final process capability with the use of the in-process measuring device.

The study showed that the Renishaw spindle probe was able to measure and account for variation that was introduced by previous steps. This allowed the CNC Mini-Mill to machine the internal pocket in the center of the aluminum block at greater dimensional accuracy (see Table 1).

When the authors analyzed the results based on the third set of hypotheses, it was more challenging to gather a conclusive result. The set of blocks processed with the Renishaw spindle probe in the X axis showed a decrease in process capability, while the Y axis showed an increase in process capability when compared to the initial process capability of the aluminum blocks. This result was linked to the extremely high initial process capability in the X axis (see Table 1). As stated in the methodology, only one of the X axis sides was machined during the initial machining process to create the aluminum blanks. This translated into all of the blocks retaining one factory edge in the X axis resulting in less variation being introduced to the overall width in the X axis. Due to less variation present in the X axis, the initial process capability was substantially higher than the Y axis. The Renishaw spindle probe showed a difference for the process capability in both the X axis and the Y axis. The process capability for the Y axis improved, while the process capability for the X axis decreased, so the authors were able to retain the third research hypothesis:

$H_1$3: There was a difference between final process capability with the in-process measuring device and final process capability without the in-process measuring device.

The ability to improve the process capability over the initial variation established by the raw material was shown with the improvement in the final process capability in the Y axis. The results showed that there was a limit in the amount of variation that the Renishaw spindle probe was able to operate within. This was shown in the decrease of the final process capability in the X axis.

Conclusion

After the authors analyzed the data collected and studied the results in regard to the three sets of hypotheses, they were able to conclude that process capability decreased in the CIM cell, due to the compounding variation introduced by each piece of linked automation. They discovered that, in order to account for this compounding variation, a Renishaw spindle probe could act as an in-process measuring device. The in-process measuring device allowed the CNC machine to account for the previous variation introduced in the system and adjust accordingly. Individually adjusting the machining process for all of the aluminum blanks allowed the final process capability to improve over the initial process capability. This showed that the process was able to create a part containing less variation than initially present in the raw material.

In order to revalidate the information gathered from this study, it was important that the study be completed again while focusing on a few areas that could possibly cause unintended variation. Revalidating the data collected will help prove that the Renishaw spindle probe was able to improve the process capability within the CIM cell.

The first area that could be adjusted in future studies is the way that tool wear was monitored. An issue occurred with tool breakage while machining the 100 aluminum blocks without the use of the Renishaw spindle probe. Tool breakage caused the amount of tool wear that each block experienced without the probe to vary. In order to eliminate the varying tool wear experienced during the machining process, the tool touch off setter could be used the same way it was used on the blocks processed with the Renishaw spindle probe. Before each block was machined, the tool could be measured with the tool touch off probe. This would eliminate the issue of varying tool wear between the sets of blocks processed with and without the probe, while still determining if the Renishaw spindle probe had the capability to eliminate compound process variation.

Another area of variation that could be more closely monitored in future studies is the means used to measure the aluminum blocks. Instead of using an individual to measure all of the data with a digital caliper, a jig could be used to eliminate human variation that was introduced into the study. If the caliper was held incorrectly during a measurement, the measurement was retaken by the operator, but there is still the potential to introduce an incorrect measurement into the study. If a jig was used that would prevent the operator from introducing human measuring error into the study, the data would increase in validity.

Along with these issues, there was also a problem with the vise that prevented the robot from consistently loading the aluminum blocks into the cell. Over time, the vibrations present in the CNC milling machine prevented the jaws on the vise from opening to their full reach. This restriction on the opening of the jaws caused the robot to incorrectly load the aluminum blocks. When the blocks were incorrectly loaded, the CIM cell had to be shut down and restarted. Since the CIM cell had to be restarted each time the robot incorrectly loaded the part, this prevented the CIM cell from running the desired batch size without restarting the cell. Constantly restarting the cell could have introduced unexpected variation into the data that could be eliminated in future studies, now that the vise has been repaired.

The last revision that could be made in future studies deals with the X side retaining one of the factor edges. The authors attributed the high initial process capability in the X axis to the fewer number of steps that were present when processing the aluminum blocks on the X axis. If both sides of the X axis were processed on the manual milling machine then the process capability would more closely resemble the initial process capability of the Y axis. In future studies, the same steps used to process the Y axis should be used to process the X axis to ensure a more consistent initial process capability for the work piece.

References

[1] Saygin, C. (2004). A Manufacturing laboratory for integrated hands-on applications. *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*.

[2] Zhou, Y., & Chuah, K. B. (2002). Computer-integrated manufacturing in china: A report of industrial field surveys. *International Journal of Operations & Production Management, 22*(3), 271-288.

[3] Pyzdek, T., & Keller, P. A. (2010). *The six sigma handbook, a complete guide for green belts, black belts, and managers at all levels*. (3rd ed.). McGraw-Hill Professional.

[4] Hart, M. K. (1992). Quality tools for decreasing variation and defining process capability. *Production and Inventory Management Journal, 33*(2), 6-6.

[5] Cheng-Che, C., Chun-Mei, L., & Hsiao-Yu, N. (2010). Measuring process capability index C pm with fuzzy data. *Quality and Quantity, 44*(3), 529-535.

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THE LEADERSHIP CUBE: EXAMINING THE BALANCE BETWEEN LEADERSHIP ATTENTION TO PRODUCT, ATTENTION TO PEOPLE, AND COMMITMENT TO PROCESS

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Abstract

Few professions are as process-oriented as engineering. In an effort to achieve optimum efficiency, engineering organizations tend to create, and adhere to, strict processes. This can sometimes lead to a lack of consideration for the needs of the organization's human resources. Process may also be adhered to in situations where the production of the organization fails to meet schedule or budget. How, then, should an organization's leadership determine an appropriate balance of attention to product, attention to people and commitment to following process? In this study, the author examined the literature of the field of leadership studies and proposed a metric for examining the balance between these three attributes.

Introduction

Leaders face the constant challenge of trying to correctly align their organizational operations in an effort to produce success. This challenge is present regardless of whether the organization is technical, non-technical, industrial, academic, religious, recreational, for-profit, or not-for-profit in nature [1]. It is necessary to look within to determine what aspects of an organization receive attention from its leaders as they endeavor to plot a path to success [2]. Pearson [3] expressed that there are three key aspects of an organization that leadership needs to look at: product, people, and process. Researchers in the field of leadership studies have expanded independently on these three critical aspects that must be considered by the leadership of any organization [4].

The three aspects just mentioned, attention to product, attention to people, and commitment to process, have been found to be relevant as to how they interact to affect organizational behavior, performance, and quality [5]. The term "product" is generally used to refer to the outcome that the organization intends to create [6]. This product may be a physical component or system, but it may also be a service supplied or even a qualified graduate who has completed specific training. Attention to people encompasses the management of human resources within an organization [7]. They are the fundamental resource of an organization and are one important consideration that must be kept in mind if any type of business is to remain both successful and sustainable. Finally, the third aspect, organizational process, refers to the progression of steps or actions that are taken, in a planned and organized fashion, to achieve the resulting product [8]. How leaders deal with these three factors can impact the success of an organization [9].

People and Product

One aspect of an organization's behavior includes how people are treated within an organization [7]. In the business world, this may include the company's staff, while if the business is a club or religious organization, these people may be the members [10]. The manner in which both product and people are treated by the organization is dictated, to a great extent, by the behavior of the organization's leaders [11]. A quantitative study of 246 organizations by Weiss [12] examined how human resource management systems contribute to organizational success. He determined that proper human capital management derives from leaders who treat their people within the organization as being equal in importance to the financial resources, the capital equipment, and the product of the organization. This study indicated that today's leaders are coming to recognize the critical role that employee stakeholders play in organizational success.

Another study, by Winsborough et al. [7], conducted qualitative research that indicated that a leader must provide followers with a sense of security and respect, as well as communication of a meaningful vision for the organization. Failure to provide these by a leader shows either a lack of understanding of the needs of the organizational community or a lack of concern for meeting follower needs. Yet another study [13] examined the correlation between a leader's social responsibility to people and the financial success of the organization by evaluating the social rating scores and market capitalization scores for nearly 1000 firms. The results showed that the correlation found between the social rating scores and financial success indicated a solid basis for business leaders to make their decisions with attention paid to the effect on the people impacted by those decisions. One of the great challenges of leaders today includes understanding what people need from a leader and how to meet these needs, while simultaneously balancing the other needs of the organization [2]. Consideration of these needs and the effort to meet them by the leader indicates the level of attention he or she pays to the people in the organization, which research shows is one indicator of success. However, the entire basis for leadership action cannot be based solely on the needs of the people. Without a viable product, the organization will not long remain in operation. Thus, the organization's relationship to its product must also be considered.

A series of case studies [6] involving the business results of several global companies found that many are adjusting the way they think about their traditional product. Historically, businesses have viewed the commodity that they produce as being their sole source of income. Leaders would, therefore, manage their organizational results by creating demand for a new product that could be priced at a premium and then driving demand for the product upward, as the marketable price diminished with time.

However, in today's marketplace, companies are more inclined to seek new market spaces, perhaps focusing attention on ancillary products or services which support their existing customers, even to the extent of fostering situations where the customers need less of the primary product but keep corporate income up by purchasing the ancillaries. The key point in this study was that organizations that pay adequate attention to their product ensure continued organizational growth and success. Research by Pulm and Clarkson [9] echoed the fact that business products are evolving and becoming more complex. Traditional approaches do not lend themselves to developing complex products. Their study indicated that the conceptualization, planning, scheduling, marketing, and control of the processes that produce the products cannot efficiently be left to develop on their own. They also showed how an organization uses its resources, which includes its people, to develop its products. Thus, organizational leaders must always be balancing their attention to people and product.

An examination of research regarding the attention paid to the people and product of an organization began with the Ohio State University Leadership Behavior Description Questionnaire (LBDQ) [14]. The LBDQ was developed during the post-World War II years when there was a considerable amount of interest in leadership styles and methods, but no satisfactory theory or definition of the factors that constituted leadership. Subsequent studies by Blake and Mouton [15] extended this work and led to the creation of their Managerial Grid. The Grid was constructed in order to examine the balance of attention shown by leaders to an organization's people and products. It has been used extensively in a wide variety of manufacturing and service industries to evaluate leadership behaviors [16].

The traditional Managerial Grid consists of two axes, one representing a leader's attention to people and the other representing attention to product, or organizational output, as shown in Figure 1. If a leader scored high in attention to both people and product, s(he) would be located in the upper right of the Grid with a score of something akin to a (10,10). A leader who paid little attention to either would be located on the lower left of the Grid, with a score close to (1,1).

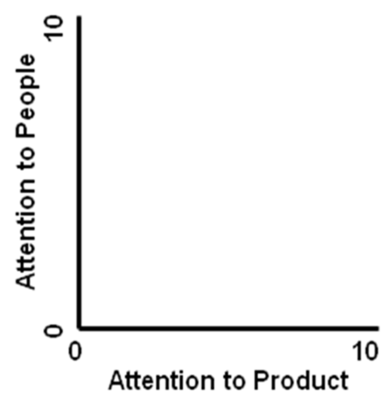

Figure 1. The Traditional Managerial Grid [14]—A Plot of Leadership Attention to People against Leadership Attention to Product

Brolly [17] demonstrated that the use of the Managerial Grid in group settings helped participants evaluate their leadership shortcomings and influenced participants to change attitudes, which can bring about progress within an organization. Malouf [18] verified a similar effect, which resulted when leaders recognized their need to improve, as measured by the opinions of their subordinates and coworkers during completion of a Grid exercise. This was done by taking the numerical scores from a number of participants in Managerial Grid seminars and statistically analyzing them in order to arrive at a quantitative conclusion which was consistent with the researcher's qualitative observations. The Managerial Grid has also been used by researchers such as Malouf and Brolly to examine how the predictor variables of attention to people and attention to product relate to the outcome variable of success. Managerial Grid instruments have existed for years and are still actively discussed in modern writings on leadership and management, and studies of leadership traits [19], [20].

Organizational Process

Another important aspect of how an organization is run revolves around its processes and how well those processes are adhered to. Engineering is a field that is strongly process driven [21]. Engineers tend to think and problem solve in a logical, analytical, consistent, and sequential fashion [22], [23], so there is a natural tendency for them to follow established process steps. Thus, engineering organizations are among the most process driven. These processes may be created and followed with precision virtually to the exclusion of consideration for other parameters.

The Blake and Mouton Managerial Grid does not consider organizational processes. Since engineering organizations are strongly process driven, the traditional Grid, therefore, misses one of the strongest drivers in an engineering organization. However, other researchers have examined how creation of an organizational process influences organizational success [24]. Schrikant and Grasman [25] and Tumbeaugh [26] examined case studies which implied that selecting the correct organizational processes, or re-engineering current processes to improve them for the organization's situation, enhanced organizational success.

Jovanic [27] conducted a study of over 200 companies, which pointed out the significance of implementing appropriate processes. This study emphasized the significance of process in bringing about a better product and, thus, increased profits and improved position in the marketplace, both of which are common measures of organizational success. A number of other studies indicated that design of a good process correlates positively to creation of a good product, which leads to a need for review of the literature of process studies. Crowston [28] indicated that creating a process in an organization required the management of a number of interdependencies among tasks and resources. Shuendraq and Oswari [29] indicated that the approaches encompassed by the process may be strategic, operational, organizational, or a combination thereof, and can govern a number of organizational aspects including financial, human resources, operations, customer relations, marketing, and sales. Olson [30] examined the re-engineering of business processes to focus attention on organizational output, or product, and to address customer needs with results showing that positive modification of processes correlated with organizational success. Similarly, Rigby [24] conducted a study which recognized that when a process is improved, the product is enhanced. Cooper and Edgett [31] performed a study of 211 businesses with a focus on performance metrics to determine whether such processes indeed worked. Their research indicated that most firms use some form of process to direct changes within their organizations. Top-performing businesses were identified and those practices that distinguished successful businesses from the lower performers were examined. The conclusion was that development of appropriate processes correlated positively to successful innovation.

Research by Dietz [32] recognized that organizational processes needed to be designed appropriately for their resources, their application, and their objective, just as mechanical components must be designed with those same things in mind. Dietz realized that the active elements in an organization were its people, and they were its primary resource. Thus, the aspects associated with these human beings and their needs had to be accounted for in the design of processes, just as the individual components in a working mechanical assembly had to be considered. Schrikant and Grasman [25] pointed out that every successful organization should understand its own resource needs in order to be successful. These needs include the manpower necessary to perform the organization's tasks. In order to ensure appropriate resource staffing, the organization must understand its skill needs, project its resource quantity and allocation needs, and develop mechanisms for finding, hiring, and retaining the personnel that will allow the organization to meet those staffing needs. Thus, Schrikant and Grasman inferred that the organizational processes a company develops need to factor in the impact on the people of the organization in order to ensure that the right employees are found, hired, and integrated into the organization's processes.

In summary, few fields of endeavor are as process-oriented and process-driven as engineering. Engineering organizations usually operate under rigid processes governing everything from their organizational interaction to the manner in which their conceptual ideas advance to preliminary designs and then to detail designs through analysis to manufacturing, testing, and release. Therefore, it makes sense to consider a means of examining an organization's attention to product, attention to people, and commitment to process, simultaneously.

Creating a Balance of the Three Ps

The objectives of an organization may be many and varied, depending on the type of organization and the reason for its existence. Regardless of organizational type, however, leaders must place some level of attention on product, attention to people, and commitment to following process. In engineering organizations, there can be a concern that too strong of an adherence to process may restrict needed attention to the other parameters. Exactly how the three-way balance between the three parameters of people, product, and process can be achieved has not been a point of significant research and discussion [33].

Turnbeaugh [26] researched the impact of processes in improving organizational culture. The most appropriate process for an organization was noted as one that elicited desired organizational culture changes which, in turn, promoted the desired outcome. The study emphasized that appropriate process strategy improved the business outcomes, or product, of the organization; but since cultural change involved the people of the organization, the three were intertwined. Similarly, Pulm and Clarkson [9] made observations about the coherence between the product, the process, and the teams of people within an organization. These research studies made it clear that the process that drives product development needs to be viewed as part of a social system involving the organization's product and its teams of people.

A recent review of the literature [4] found that a number of researchers implied the existence of an interrelationship between the attention an organization paid to its product and its people and its commitment to following process. However, none of the articles addressed all three simultaneously; some, though, such as Pulm and Clarkson [9] and Roger et al. [33], pointed out the need for more research in this area. The Managerial Grid, as developed by Blake and Mouton [15] provides a way to measure and compare leadership and management styles, but only with regards to the attention that leaders pay to product and people. The Grid is still considered relevant in leadership circles [20]; however, several researchers including Gatfield [34], Martel [35], and even Blake and Mouton [36] themselves have postulated the addition of a third axis to the Grid to expand its usefulness. To date, none have ever considered process as the third variable.

In today's business environment, significant attention is paid to the creation of business process, especially in engineering. Therefore, a new version of the Grid could be created, in which the original two axes of attention to people and attention to product would be joined by a third axis representing commitment to process. Perhaps this new instrument should more appropriately be referred to as the Leadership Cube.

It might be argued that Blake and Mouton's Managerial Grid could be assumed to capture process as a part of its product parameter, since engineering organizations do produce the process that they use to create the ultimate result that they create and market. However, the aspect of commitment to following process would not be captured. In other words, how does leadership's commitment to adhering to set processes intermesh with their attention to product and attention to people in order to result in organizational success or lack of success? The question at issue is that once the process is created, is it adhered to, and how strongly, or with how much commitment?

The Leadership Cube could be further used in studies in which success would be the dependent variable of organizational success. Success could be determined using financial measures; however, necessary data are often challenging to acquire [9], [37] and subjective measures such as perception of success by stakeholders is, therefore, suggested as the best measure [38]. Regardless of the metric used, the assumption is that success of the organization would be a result of its balance of the three predictor variables: attention to people, attention to product, and commitment to process. A dependent variable representing an assessment of success would populate the volume of the Cube. Thought of as a mathematical function, organizational success (S) is a function of three independent parameters: leadership attention to product (P_1), leadership attention to people (P_2), and leadership commitment to process (P_3). Expressed functionally, $S = f(P_1, P_2, P_3)$.

In this study, then, the author proposed the use of a three-axis graph combined with a color gradient to display the data. If an organization's success can be broken into categories of unsuccessful, neutrally successful, and highly successful, then colors can be assigned to these categories ranging from red, to yellow, to blue. If each data point on the three-dimensional grid of attention to people, attention to product, and commitment to process were plotted with its associated success-oriented color, then there would be an expectation that the uppermost quadrant of the Cube will tend to be blue, associated with higher success of an organization, while organizations with an imbalance between the three parameters or a lack of attention to all of them would be expected to have colors associated with lower performance. Organizations with a less balanced approach would be expected to fall furthest from the 45^o diagonal connecting the corners of the cube. Organizations paying little attention to any of the three attributes would be expected to lie near the diagonal but closer to the origin. The gradient of color seen in this three-dimensional Leadership Cube would permit a determination of the relative balance of the three independent parameters, or predictor variables, as they relate to the dependent parameter, or outcome variable, of organizational success. From this data analysis, it is possible to assess the relationship between organizational success and the three independent variables of attention to product, attention to people, and commitment to process.

Measurement

In order to construct the Leadership Cube, there must be a means for measuring the three independent parameters (attention to product, attention to people, and commitment to process) and one dependent parameter (organizational success). The Blake and Mouton Managerial Grid was initially based on the Ohio State University Leadership Behavior Description Questionnaire (LBDQ), which has been in use since the 1960s. More recently, instruments have been developed for use specifically in Managerial Grid studies, including the *Styles of Leadership Survey* [39] and the *Leadership Appraisal Survey* [40], both of which yield results examining the relationship between attention to product and commitment to process. A more recent survey instrument was developed [4] to fill a gap in the area of leadership studies research pertaining to commitment to following process. Using a combination of these instruments, or similar metrics, quantitative rankings on a scale of 1 to 10 can be obtained for the three independent parameters of attention to product, attention to people, and commitment to process. The remaining dependent variable is organizational success, which now needs to be discussed in more detail.

Profit and shareholder value are often used as quantitative measures of business success, but Pulm and Clarkson [9] found that financial measures are not the best measure of success since company financial records or other competition-sensitive performance indicators may not prove readily accessible, and also because today's society frequently conceptualizes organizational success as perception-based rather than being based on economic or monetary-based data. Cummings and Worley [37] found that utilizing such financial-based measurements as success indicators can actually be problematic, due to their connection with the ever-changing market and economic conditions allowing the economic ebb and flow to potentially create favorable conditions for some mismanaged organizations. Lowe and Galen [41] reached this same conclusion; they found that employee perceptions predicted leadership effectiveness better than financial indicators such as profit versus loss, or market share loss or gain. Cameron et al. [42] indicated that employee perceptions are a measure of morale and, ultimately, the organization's productivity and sustainability. Therefore, perception can predict organizational performance. They also indicated that organizational decline was predicted by negative indicators such as resistance to change, low morale, and high turnover, the effects of which are also captured in the perception measurement. Thus, subjective measures of organizational success, such as the perception of success by members of the organization, may well be chosen as opposed to more objective measures of performance in organizations [38]. Regardless of which measure of organizational success is used, the tools have just been described which would allow the Leadership Cube to be constructed.

In an effort to show how this Leadership Cube would display the parameters just discussed, data to populate a trial Cube was synthesized from a previous research study [4]. The three independent, predictor variables related to product, people, and process are plotted on the three axes of the Cube. The data points that populate the volume of the Cube are color-coded from red (low success) through orange, yellow, and green, to blue (high success). To clarify this, a perfect correlation of success to all three parameters would place red data points nearest the origin of the axes, and blue data points furthest from the origin, closest to the opposite corner, with a progression from red through orange, yellow, and green toward blue as you moved further from the origin of the axes. The fact that the plot of the data does not totally show this trend is due to data variability, since the correlation is not perfect between the three parameters and success. However, the less successful organizations (red and orange) do tend toward the origin of the axes and the more successful organizations (green and blue) do tend toward the opposite corner, which is the expected result. The Cube plotting the same data is shown in Figures 2 and 3 from two different viewing angles. If the Cube were merely plotted as Blake and Mouton did their Grid, but with a third axis added, then it becomes extremely difficult, if not impossible, to envision how the data points lie relative to each other and the axes. It is far easier to examine them in a three-dimensional view which can be rotated to examine their relative position better; this was done in Figures 2 and 3, with Figure 2 showing the Cube's applicability for simultaneously displaying organizational success against the independent variables of attention to product, attention to people, and commitment to process.

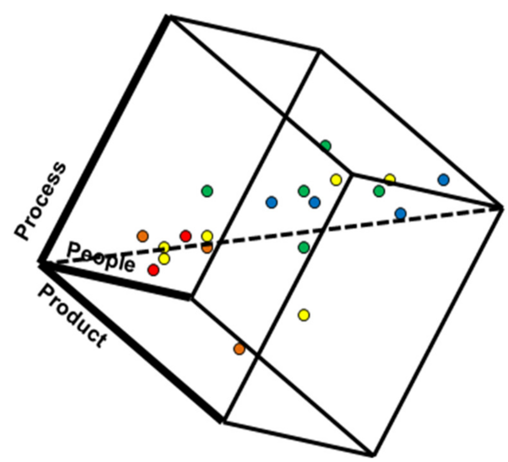

Figure 2. The Proposed Leadership Cube Populated with Data from a Recent Research Study [4]

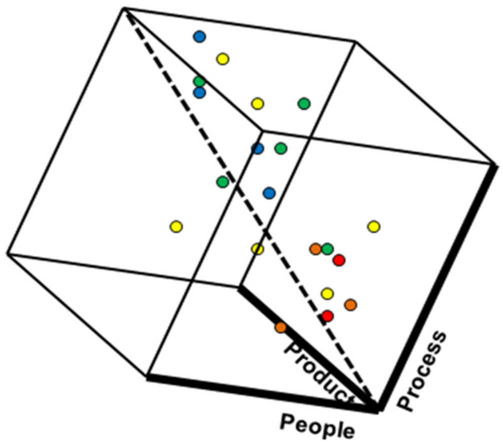

Figure 3. The Leadership Cube Data from Figure 2 Viewed from an Alternative Perspective

Conclusion

In today's engineering organizations, leaders must determine how to balance the attention they give to the organization's people, its product, and their commitment to following processes. Particularly in engineering, there can be a concern that processes may take the lead role, to the detriment of the other parameters. Measurement tools already exist for examining the attention paid by leaders to each of these parameters independently. This current study showed evidence from research in the field of leadership studies that indicated the importance of examining these three parameters simultaneously. In this study, the author developed a mechanism, referred to as the Leadership Cube, in which these three parameters, used as independent variables, could be displayed against the dependent variable of organizational success. This metric could then be used to evaluate individual leaders or compare different organization leadership teams against each other, similar to how the Managerial Grid has been used for several decades. An application of this Leadership Cube was examined using data synthesized from a previous study. The results indicated the general applicability of the approach, as well as supporting the expected results that a good balance of leadership attention to product, attention to people, and commitment to process tends to result in success.

The case was made in this paper that highly process-oriented fields, such as engineering, could benefit from an assessment using the Leadership Cube in order to determine how strongly the success of the organization is tied to an equitable balance of attention to product, attention to people, and commitment to process. It is currently undetermined how strongly commitment to following process relates to success in other fields, where adherence to process may not be as readily apparent. Religious organizations, social science fields, service organizations, and the arts are areas where this connection may not be as strong. However, this is speculative, not verified and, as such, would benefit from additional research and possible application of the Leadership Cube for further examination.

References

[1] Malm, J. (2008). Six community college presidents: Organizational pressures, change processes and approaches to leadership. *Community College Journal of Research & Practice*, *32*(8), 614-628.

[2] Bennis, W. (2007). The challenges of leadership in the modern world. *American Psychologist*, *62*(1), 2-5.

[3] Pearson, Q. (2011). Three "Ps" of publishing in the JMHC: People, process, and product. *Journal of Mental Health Counseling, 33*(3), 191-195.

[4] Hylton, P. (2013). *Development of an instrument for the measurement of Leadership commitment to organizational process*. ProQuest Dissertations and Theses. (1431981413).

[5] Carter, L., & Carmichael, P. (2011). The best of best practices: Critical success factors for identifying and measuring industry-leading management solutions. *T+D*, *65*(8), 40-44.

[6] Vandermerwe, S. (2000). How increasing value to customers improves business results. *Sloan Management Review*, *42*(1), 27-37.

[7] Winsborough, D., Kaiser, R., & Hogan, R. (2009). An evolutionary view: What followers want from their leaders? *Leadership in Action*, *29*(3), 8-11.

[8] Botha, G., & Van Rensburg, A. (2010). Proposed business process improvement model with integrated customer experience management. *South African Journal of Industrial Engineering*, *21*(1), 45-57.

[9] Pulm, U., & Clarkson, J. (2005). The meaning and coherence of process, organization and product in engineering design. *Journal of Integrated Design & Process Science*, *9*(1), 55-66.

[10] Beatty, K., & Quinn, L. (2010). Strategic command taking the long view for organizational success. *Leadership in Action*, *30*(1), 3-7.

[11] Luckett, M. (2005). *The effects of leadership grid training on transformational leadership in a Fortune 500 company*. Dissertations & Theses: The Humanities and Social Sciences Collection. (AAT 3161206).

[12] Weiss, D. S. (2005). HR Metrics that Count: Aligning Human Capital Management to Business Results. *Human Resource Planning*, *28*(1), 33-38.

[13] Stanley, S. (2011). *A correlational study examining the relationship between social responsibility and*

financial performance. Dissertations & Theses: The Humanities and Social Sciences Collection. (AAT 3453666).

[14] Bass, B. (1974). Bass and Stogdill's Handbook of Leadership. New York, NY: Free Press.

[15] Blake, R., & Mouton, J. (1975). An overview of the Grid. *Training & Development Journal*, *29*(5).

[16] Williams, A. (1971). The Managerial Grid: Phase 2. *Occupational Psychology*, *45*(3/4), 253-272.

[17] Brolly, M. (1967). The Managerial Grid. *Occupational Psychology*, *41*(4), 231-237.

[18] Malouf, L. (1966). Managerial Grid evaluated. *Training & Development Journal*, *20*(3), 6.

[19] Thrash, A. (2010). *Leadership in higher education: An analysis of the leadership styles of academic deans in Ohio's 13 state-supported universities*. Dissertations & Theses: The Humanities and Social Sciences Collection. (AAT 3378893).

[20] Northouse, G. (2010). *Leadership: Theory and practice* (5th ed.). Thousand Oaks: Sage publications.

[21] Reed, P. (2013). Don't just cover the Engineering Design Process. *Technology & Engineering, 73*(2), 16-20.

[22] Lumsdaine, M., & Lumsdaine, E. (1995). Thinking preferences of engineering students: Implications for curriculum restructuring. *Journal of Engineering Education*, 84(2), 193-204.

[23] Boer, A., Toit, P., Scheepers, D., & Bothma, T. (2013). *Whole brain learning in higher education*. Philadelphia: Elsevier.

[24] Rigby, D. (1993). The secret history of process reengineering. *Planning Review, 21*(2), 8.

[25] Schrikant, J., & Grasman, S. (2011). Work force planning the systems way. *Industrial Engineer: IE*, *43* (7), 35-39.

[26] Turnbeaugh, T. (2010). Improving Business Outcomes. *Professional Safety*, *55*(3), 41-49.

[27] Jovanic, G. (2010). The impact of business process reengineering on small and medium sized companies – research results. *5th International Conference on Applied Statistics.* Retrieved from Academic Search Premier database. *(64925055)*

[28] Crowston, K. (1997). A coordination theory approach to organizational process design. *Organization Science*, *8*(2), 157-175.

[29] Shuendra, E. & Oswari, T. (2011). Business process management in organization: A critical success factor. *Journal of US-China Public Administration, 8*(1), 110-120.

[30] Olson, P. (2005). *The impact of multiple improvement strategies on organizational effectiveness: A case study of team-based projects*. ProQuest Dissertations and Theses. (305356722).

[31] Cooper, R., & Edgett, S. (2012). Best practices in the idea-to-launch process and its governance. *Research Technology Management*, *55*(2), 43-54.

[32] Dietz, J. (2006). The deep structure of business processes. *Communications of the ACM*, *49*(5), 59-64.

[33] Roger, A., Marcel, F., & Lopez, A. (2010). Business process requirement engineering. *International Journal on Computer Science & Engineering*, *2*(9), 2890-2899.

[34] Gatfield, T. (2005). An investigation into PhD supervisory management styles: Development of a dynamic conceptual model and its managerial implications. *Journal of Higher Education Policy & Management*, *27*(3), 311-325.

[35] Martel, A. (2006). *The experience of followers: Investigating a link between the informal communication network and leadership.* Dissertations & Theses: The Humanities and Social Sciences Collection. (AAT 3227474).

[36] Blake, R., & Mouton, J. (1967) The Managerial Grid in three dimensions. *Training & Development Journal, 21*(1).

[37] Cummings, T., & Worley, C. (2001). *Organizational development and adjustment* (7th ed.). Mason, OH: South-Western College Publishing.

[38] Boga, I., & Ensari, N. (2009). The role of transformational leadership and organizational change on perceived organizational success. *Psychologist-Manager Journal*, *12*(4), 235-251.

[39] Hall, J., & Johnson, E., (2009). When should a process be art, not science? *Harvard Business Review, 87*(3), 58-65.

[40] Hall, J. (1971). *Leadership Appraisal Survey.* Waco, Texas: Teleometrics International.

[41] Lowe, K., & Galen, K. (1996). Effectiveness correlates of transformational and transactional leadership: A meta-analytic review of the MLQ literature. *Leadership Quarterly*, *7*(3), 385–426.

[42] Cameron, S., Whetten, A., & Kim, U. (1987). Organizational dysfunction of decline. *Academy of Management Journal*, *30*(1), 126–138.

Biography

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EFFECT OF LEARNING MATH SKILLS IN HIGH SCHOOL ON ENGINEER EFFECTIVENESS: RESULTS OF A PILOT STUDY

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Abstract

It is no surprise that aspiring engineering students are strongly encouraged to acquire mathematical knowledge as early in their academic education as possible. The engineering profession has always been linked to a solid foundation in math and sciences. In this paper, the author presents the findings of a pilot study conducted on the impact of the early or late learning of math concepts on the engineer's effectiveness. This pilot study included the use of a questionnaire generated by interviewing a group of professional engineers about their experience in math in both high school and college. The initial results from the pilot study data also indicate a correlation between taking advanced math in high school and the effectiveness of engineers' problem solving abilities, as well as on their overall performance. The results of this study were used to modify the questionnaire, data collection, and analysis process during the final stage of this project.

Introduction

Engineers are expected to be problem solvers; algebra, geometry, and calculus contribute greatly in the development of effective problem solving skills. Since engineering is not something that can be learned overnight, it seems logical that the typical prospective engineering student should take math classes as early as possible to avoid getting bogged down and distracted with other life events. The importance of studying subjects such as calculus, algebra, and geometry as an essential part of a high school curriculum for students pursuing an engineering college education has been a topic of research and discussion for many years [1].

Calculus, algebra, and geometry are considered by some as tough subjects and, in some cases, are dreaded by high school students. Some researchers [2] thought that taking higher level math classes such as calculus should be delayed until students have started their undergraduate education. Others [3] concluded that the best advice for students to successfully survive the competitive environment of engineering programs is to include algebra, geometry, and calculus in their high school curricula.

This current study concentrated on problem solving skills needed to achieve success in engineering education, as well as in professional development within engineering fields. Once it is understood how important the study of algebra, geometry, and calculus is for developing problem solving skills, instead of emphasizing the level of difficulty and the complexity, there should be a focus on identifying how these courses are of great assistance in improving critical thinking, meta-cognition, and problem solving abilities. It will be easy to see why it is crucial to encourage all those students who are planning to follow paths in engineering to include the three subjects in their high school education. This will no doubt lead to a better understanding and acceptance of their importance by students, both at the high school and undergraduate level.

The main question that needs to be answered is whether or not taking algebra, geometry, and calculus in high school helps the engineer to formulate effective problem solving skills versus those who took math classes in college only. In order to investigate such questions, it was decided to conduct a pilot study in order to gather information needed to launch a major research survey. The purpose of this current study was to investigate the influence on engineers' effectiveness of taking algebra, geometry, and calculus in high school, compared with taking the same courses at the college level. At some point in the process of learning advanced mathematics, engineers gain proficiency of the concepts. Engineers apply these concepts to their problem solving effectiveness in their daily work. This study compared and contrasted the engineers' problem solving skill effectiveness, based on when an engineer takes algebra, geometry, and calculus courses in their academic careers.

Effective Engineers

It is difficult to define engineering effectiveness, as very little research has been conducted in this area [4]. The major portion of the engineer's job relates to problem solving. It is, therefore, imperative that engineering students be taught how to solve problems [2]. Regardless of the specific field into which engineers are hired, the essential task of engineers is to solve problems. This could be in the area of construction, technology, communications, space, electronics, etc. An important aspect of engineers' work is to find new and creative ways for problem resolution in the workplace.

Producing effective engineers is the main goal of any engineering education program [4]. Most universities define such outcomes using ABET criteria. Maddocks et al. [5] defined these competencies as knowledge and understanding, intellectual abilities, practical skills, general transferable skills, and qualities. Wells [6] added collaboration and product knowledge to the competencies of manufacturing engineers originally defined by the Society of Manufacturing Engineers (SME). Male et al. [7] highlighted communication, self-management, team work, problem solving, decision making, and critical thinking as the major competencies of effective engineers. Millar [8] suggested that actions rather than knowledge define effectiveness. Newport and Elms [4] defined measurement of effectiveness to be "getting the job done" and "achieving goals". They then defined a list of 68 hypothetical qualities of effective engineers.

Mathematics Study for Engineers

There are many factors that can contribute to a student becoming a good problem solver, and one of those is definitely the study of mathematical sciences such as algebra, geometry, and calculus. Mathematically competent students are quantitatively literate [9]. Such students are capable of making balanced decisions using quantitative data. They approach novel problems and situations with their flexible thinking and knowledge of a wide range of techniques [10]. Furthermore, Windsor [11] suggested that understanding algebraic processes is a vital element of mathematical thinking and reasoning. The National Research Council identified five strands of mathematical proficiency as: conceptual understanding, procedural fluency, strategic competency, adaptive learning, and productive disposition. Creating competency in these strands supports development of effective engineering qualities [12].

In another study [3], the authors emphasized the importance of math courses such as calculus for high school students. If students wish to major in engineering, the involvement becomes virtually mandatory, as the authors also suggested that students taking advanced math in high school are more likely to graduate from four-year colleges [3]. Gorini [13] described how geometry is an essential tool for learning other subjects such as calculus, statistics, linear algebra, linear programming, and abstract algebra. Problems in the engineering workplace may be complex, with conflicting goals, involving various approaches to solutions, or information required from a variety of sources, and cooperative teamwork, along with engineering or non-engineering constraints and standards of success [14].

Several researchers [14] have argued that engineers rarely use specific knowledge and skills learned in school throughout the development of their careers and professional lives. These arguments are countered by many other researchers. Jonassen et al. [2] suggested that many of the reasoning and thinking processes that students develop in their early academic programs are not attributed to the inclusion of intensive mathematical instruction. Dudley [14] suggested that such early academic programs, along with real-life experiences, bring improvement to cognitive processes such as abstract thinking and problem solving. He also argued that people disregard the contribution of mathematics in such achievements [14].

Research Question

The literature review indicates the importance of algebra, geometry, and calculus on developing engineers. It is established that the percentage of engineers who actually use these courses on the job or in their daily professional lives is very low. On the other hand, it is also indicated that such courses have the ability to increase the cognitive learning process, which is vital for the improvement of problem solving capabilities.

The major question is when these math courses need to be taught to potential young engineers. Potential engineering students usually take these mathematics courses at high schools or in colleges/universities. Without going into the difference between a college algebra course and the same course taught at the high school level, the important question is whether or not there is a difference in the effectiveness of engineers when they took algebra, geometry, and calculus courses in high school rather than in college.

RQ1: Engineers completing geometry, algebra, and calculus courses at high school levels have a better understanding of 300- and 400-level engineering courses than the ones who completed these courses at college or university levels.

RQ2: Engineers completing geometry, algebra, and calculus courses at high school levels are better engineers than ones who completed these courses at college or university levels.

Research Methodology

To evaluate these research questions, a qualitative study followed by a quantitative study was conducted. For the quantitative research, a structured interview was conducted to inquire about three areas of interest (geometry, calculus, and algebra in high school) and their application to college level classes and real engineering problems. The purpose of the research interview was to explore the points of view of senior engineers and their beliefs on how early math classes play a role in developing characteristics needed for success, how it is defined, and especially their opinions about the research question in general. The results from the interviews of six senior automotive industry engineers with ten or more years of experience in the field were used to develop a survey questionnaire. In this paper, the author outlines the results of the pilot study of the quantitative study to authenticate the survey questions and line up for a future detailed study on the topic.

Population and Sampling Plan

A pilot study was conducted by selecting engineers from relatively large organizations in order to gauge the viability of the questionnaire. Participants' organizations were selected from the engineering alumni association database. Four major companies, including two OEM and two tier-one suppliers from the automotive industry, were selected. Participants were asked to evaluate the formatting, instructions, and distribution of responses given to each item. They were also asked about the amount of time since they took math courses, their performance, and their effectiveness as engineers. The study further looked at whether or not there was some type of relationship between their grades in the 300- and 400-level engineering courses and the time when they completed their math classes: high school or college. Participants were also asked to provide overall comments about the survey questions.

In order to qualify to participate in this study, the engineers needed to fit certain criteria outlined by Neport and Elms [8]. The potential candidates should have at least five years' worth of work experience, work for a commercial engineering company employing at least twenty employees, and be willing to participate in the study. This was important in order to ensure that the results would be reliable. Engineers with less experience might still have been learning the profession, and those working for smaller companies might have been affected by situational and environmental factors. This also created the advantage of surveying a larger number of engineers in a shorter amount of time by concentrating on larger companies [4].

Data Collection Procedures

This survey was distributed through EMU's website via LimeSurvey, a free PHP application based on MySQL and which is distributed under GNU General Public Licenses. LimeSurvey is a web-based tool, thus it is user-friendly to develop and publish the survey. It also facilitates the collection and export of data it into commercially available statistics software. The study consisted of a dependent variable, an independent variable, and three demographic variables. Sixty nine surveys were received out of which four were incomplete.

Independent Variable

The mathematics skill set and the time when it was learned was incorporated into a MATH score. MATH is a self-report inventory that focused on three aspects including: a) time when the first course in algebra, geometry, or calculus was taken, and b) time when the second course in algebra, geometry, or calculus was taken. It was a 40-item instrument, of which 10 were related to time since courses were taken, and of which 10 were comprised of a Likert-type scale measuring the fondness or affinity for mathematics courses. Remaining items were measures of possible moderating variables related to teachers and grades.

Dependent Variables

Two separate dependent variables were tested in this study. One related to Engineer Effectiveness (EE) and other on Engineering Success (ES). Engineering Effectiveness was the self-reported inventory of 25 engineers' quality items. A Likert-type scale was used to assess the degree to which the participants thought of themselves as effective engineers. Finally, Engineering Success was defined by a self-report inventory of five items about the engineers' progress in the 300- and 400-level engineering courses. All items were Likert-type scale measurements.

Data Analysis

This study involved four different types of analysis. First, descriptive statistics were used on demographic data and grades/scores. Out of 65 participants, 32% were female and 68% male. Of the respondents, 89% were in the 30-40 year-old age group and 90% had a graduate degree in either engineering or business. Also, 78% of respondents had between 7 and 15 years' worth of engineering experience. Sixty-four percent of the respondents took five or more math classes in high school. Out of this group, males (71%) took math classes earlier than females (29%).

Table 1 illustrates grade scores of two sets of participants, one completing more math classes in high school and the other more in college. A z-test of means indicated that there was not enough evidence to reject the null hypothesis and concluded that the two means were the same, thus indicating that grades in math courses are not dependent upon when they were taken.

Table 1. Grades in Math Courses

Course Taken in	Mean	Median	Sd Dev
High School	36.19	37.00	2.42
College/University	35.3	36.00	3.03
H_o: $\mu_1 = \mu_2$ P(Z<=z) two-tail = 0.3			

Table 2 represents ES statistics. Analyzing ES using z-test of means indicated that there was enough evidence to reject the null hypothesis and conclude that the two means were different, thus concluding that performance (grades) in 300- and 400-level engineering courses are dependent upon when math classes were taken (high school or college).

Table 2. Grades in 300- and 400-level Engineering Courses

Course Taken in	Mean	Median	Var
High School	3.4	3.5	0.101
College/University	3.6	3.5	0.124
H_o: $\mu_1 = \mu_2$ P(Z<=z) two-tail = 0.023			

Table 3 illustrates the correlation results. The Pearson correlation coefficient was used to find the relationship between MATH and EE, and the relationship between MATH and ES. All hypotheses were tested at the 0.05 level of significance. The results indicated that there was a strong correlation between EE (Engineer Effectiveness) and MATH (when math classes were taken during their engineering education).

Table 3. Correlations Results MATH: EE and ES

		ES	EE	MATH
ES	Pearson Correlation	1	0.358	0.297
	Sig. (2-tailed)		0.003	0.016
	N	65	65	65
EE	Pearson Correlation	0.358	1	0.812
	Sig. (2-tailed)	0.003		0.000
	N	65	65	65
MATH	Pearson Correlation	0.297	0.812	1
	Sig. (2-tailed)	0.016	0.000	
	N	65	65	65

Similarly, a significant correlation also was found to exist between MATH and ES (engineering success gauged by performance in 300- and 400-level engineering courses) at 0.05. It is interesting to note that the Pearson correlation in this case was only 0.297, indicating a weak relationship. Such a weak relationship indicated five possible outcomes: 1) a direct cause-and-effect relationship between variables; 2) a reverse cause-and-effect relation between variables; 3) a relationship between variables caused by a third variable; 4) there may be a complexity of interrelationships among the variables; and, 5) the relationship may be coincidental. As ES was defined by number of higher level engineering courses, their grades and effects of early math courses on these grades, these measures were directly related with the performance in these courses; thus, all of the above outcomes can be rejected except the direct cause-and-effect relationship between MATH and ES.

Conclusion

This pilot study was conducted for viability of a research instrument. The results of this pilot study yielded some interesting outcomes. Grades of engineers in math courses were not dependent upon when they were taken, either high school or college. But grades in 300- and 400-level engineering courses were dependent upon time when math classes were taken. Initial data indicated that there was a significant relationship between engineers' effectiveness (EE) and engineers who took more math courses in high school. The same group of engineers also correlated significantly with engineers' performance (ES) in 300- and 400-level engineering courses. However, there were differences in responses for ES and EE when compared with the MATH scores. One had a very high correlation (EE) and the other (ES) had a low correlation, indicating that responses to success criteria questions were significantly overstated.

Using the participants' comments, it was concluded that there were too many questions related to engineering effectiveness. Questions related to communication capabilities of engineers were identified as ones that could be omitted. There was a difference of opinion with respect to the total number of math courses completed during engineering programs. It was indicated that certain Carnegie Research One institutions require more math courses than others. Participants also commented on certain self-evaluation questions (used for ES). A few thought that participants might not rate themselves accurately on certain measures related to self-evaluation as engineers, especially about their grades. This was also indicated from this current analysis. Such responses have high means and low standard deviations. It was, therefore, decided that in the final research study that quality/success measures for engineers (for ES, including evaluation) should be through other indicators. Further investigation will be made in these regards in the final study by modifying survey questions, and changes will be made in the final instructions and guidelines for the survey. This current study helped in modifying the research instrument and data-collection process, so that during the final research study, data collection and analysis can reliably validate the results.

Acknowledgements

The author would like to acknowledge Ms. Olga and Mr. Hahka, graduate students in the Engineering Management program, for their literature review work on this topic.

References

[1] McFarland, D. A. (2006). Curricular flows: Trajectories, turning points, and assignment criteria in high school math careers. *Sociology of Education*, 79, 177–205.

[2] Jonassen, D., Strobel, J., & Lee, C. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education*, *95*(2), 139-151.

[3] Breakthrough Collaborative. (2012). Calculus: It's not just for math majors. Retrieved from http://www.breakthroughcollaborative.org/sites/default/files/Advanced Math research brief.pd.

[4] Newport, C. L., & Elms, D. G. (1997). Effective Engineers, *International Journal of Engineering Education, 13*(5), 325-332.

[5] Maddocks, A. P., Dickens, J. G., & Crawford, A. R. (2002). The Skills, attributes and qualities of an engineer, encouraging lifelong learning by means of a web-based personal and professional development tool. *ICEE 2002*, *UMIST*, Manchester, 18-22 Aug.

[6] Wells, D. L. (2009) Revisiting Core Competencies of Manufacturing Engineering in an Era of Technological Revolution. Retrieved from http://claymore.engineer.gvsu.edu/ocs/index.php/smetexas2009/METS2009/paper/view/177/11

[7] Male, S. A., Bush, M. B., & Chapman, E. S. (2009). Identification of competencies required by engineers graduating in Australia. *Proceedings of the 2009 AAEE Conference*. Adelaide.

[8] Millar, C. W. (1990). Keeping the other eye open, Proc. Australasian Association for Engineering Education. *2nd Annual Convention and Conference*. Monash University, Melbourne.

[9] Usiskin, Z. (1995). Why is algebra important to learn? American Federation of Teachers. Retrieved from http://www.garnermath.com/downloads/Usiskin_Why-is-Algebra-Important.pd

[10] Schoenfeld, A. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. In D. Grouws (Ed.), *Handbook for Research on Mathematics Teaching and Learning* (pp. 334-370).

[11] Windsor, W. (2010). Algebraic thinking: A problem solving approach. In L. Sparrow, B. Kissane, & C. Hurst (Eds.), *Shaping the future of mathematics education*. Proceedings of the 33rd annual conference of the Mathematics Education Research Group of Australasia.

[12] Kilpatrick, J., Swafford, J., & Findell, B. (2001). Adding it up: Helping children learn mathematics. Mathematics Learning Study Committee, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: *National Research Council*. National Academy Press.

[13] Gorini, K. (2003). Further steps: Geometry beyond high school. *New England Mathematics Journal*, Retrieved from http://www.mum.edu/Customized/Uploads/ByDate/2013/May_2013/May_8th_2013/gorini_furthersteps42761.pd

[14] Dudley, U. (2013). In Mathematics Necessary? DePauw University. Retrieved November 13, 2013, from http://www.public.iastate.edu/~aleand/dudley.html

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INTERNATIONAL EXCHANGE: THE ATTITUDES AND ASPIRATIONS OF TECHNOLOGY EDUCATION STUDENTS IN THE UNITED STATES AND SOUTH AFRICA

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Abstract

The incorporation of technology promoting workforce globalization and mobility is important for 21st–century learners' academic programs. Technology Education degree programs are an avenue to learn more about technological processes and how to implement those processes into both the educational and workplace arenas. Since technology allows unlimited global access, students of such programs gain applicable knowledge to solve real-world problems; thus, being prepared for occupational and geographical mobility. In making the global comparison, the Technology Education students at Jackson State University in the U.S. and the University of Kwa-Zulu Natal in South Africa participated in a research study to evaluate their attitudes and career aspirations of Technology Education degree programs' preparation for a global workforce. The results of this pilot study identified student attitudes toward Technology Education programs. Results also identified how the programs have modified students' attitudes towards technology and how the programs prepared them for their desired careers.

Introduction

Technology continues to direct our society through constant change. Advances in technology impact daily lives, work, and educational arenas by granting access to vital resources. As technology is deemed as a societal necessity, entities must be in place to educate people on various technological applications. Technology Education promotes student education of technology applications into the academic and the workforce arenas. According to the Technology Education Labs [1], Technology Education is a unified, experience-based instructional program designed to enrich student knowledge of and competencies with technology. This includes technology's evolution, systems, various technologies, application, and societal and cultural importance. Technology permits global interaction that connects all nations. Academic programs are promoting more globalized approaches to enhance students' technological proficiencies; thus, enabling students to have more opportunity for geographical and occupational mobility.

Literature Review

Since technology assists in the world-wide connection, a globalized approach should be taken with education and work**.** Globalization gains great attention as educational and workforce competition intensifies. Al-Rodhan and Stoudmann [2] affirmed that globalization is the progression of international incorporation occurring from the transaction of world outlooks, merchandises, concepts, and other cultural facets. Essentially, globalization promotes practices that escalate world-wide collaborations of coast-to-coast and social resources. With this being the direction that our world has embraced, educational systems must have rigorous academic programs in place to promote globalization in education. Misra and Bajpai [3] further asserted that the characteristics of globalization dynamics have ended traditional boundaries among nations, regions, and ethnic divisions. The entire world has rapidly become a global community, and trends in the 1980s and 1990s influenced educational policies all over the World.

According to Misra and Bajpai [3], education is the fundamental means of promoting the skills of globalization. There should be a sufficient supply of ambitious teachers promoting global diversity and workforce preparation. Therefore, a solid program of professional education for teachers on every academic level is essential for educational enhancement. As stated by Wildavsky [4], the U.S. should use higher education as a mechanism to promote more opportunities through globalization. Neither a steady attrition in the U.S. of students nor the occurrence of aspiring new foreign competitors suggests that American universities are on a predictable and steady decline. Wildavsky further asserted that national competition, improvement of human capital, and economics benefit through better education. By eliminating local barriers, recruiting quality students, promoting international student exchange, nurturing national and international research collaboration, and enhancing research universities in Science, Technology, Engineering, and Mathematics (STEM), the U.S. will continue to flourish in its academic merit and extend its overall global success. With globalization being at the societal vanguard, it supports both occupational and geographical mobility.

One way America embraces mobility is through companies that send employees abroad to work [5]. Caligiuri et al. [5] stated that companies are able to employ people from other countries to work within respective internal organizations. In other instances, jobs, rather than people, are sent to other international locations through the use of off-shoring (i.e., relocating employees and certain business functions to foreign countries) by organization. This is a component of occupational mobility that allows people to work collaboratively to globally share knowledge and expertise.

Occupational mobility permits an employee to change careers and/or rank in the same occupational arena. In this case of mobility, one has the opportunity for different career transitions such as change of position within the same organization, change of job classification within the same organization, and change of organizations. Occupational mobility may be employees' top choice as they seek employment improvement and stability. Others may pursue new positions that will render upward mobility. In lieu of employers, promotion conditional acceptance must be considered in order to change the workplace. This type of mobility is encouraged during relocation or restructuring of the organization (e.g., merger, consolidation activities, etc.) [6]. While occupational mobility supports career advancement, geographic mobility provides economic opportunities and social advancement.

According to the U.S. Census Bureau, geographical mobility denotes people's movement within the U.S. from one location to another. Movers are categorized by their reasons for moving and their individual preferences. These moves can consist of international migrations, or they can simply focus on commuting arrangements [7]. Geographic mobility greatly influences many sociological factors in a community, and it is an existing academic research topic that differs between regions depending on official policies and conventional social norms. Population mobility results from local economic growth with demanding regional service, and is influenced by governmental administrative changes [8]. Specialized workforces in industrializing countries have ignited innovative interests among workers to pursue different career prospects.

Media has served as a mechanism to exhibit the western world and diversified lifestyles. Western media romanticizes youthful and independent images of men and women, who lead robust, distinctive, empowered lifestyles. Globalization may pose a threat to former absolute social norms and redirect cultural value away from previous traditions. The focus may lead to both distinctiveness and market-friendly concepts. This, united with a transfer and specialization of work, has in many ways made variability more than standard [9]. This is a result of geographic dispersion. Caliguri et al. [5] contended that geographic dispersion occurs when organizations operate across borders and coordinate operations across borders in order to be successful. The authors further asserted that geographic dispersion contributes to making operations more complex in the international arena, which encourages multiculturalism and where technology is the instrument that connects the cultures and overall nations. Technology Education serves as a key component for preparing for such transactions and transitions.

Technology Education in the U.S.

Technology Education in the U.S. evolved from Vocational (now Career and Technical) Education. The International Technology Education Association (now the International Technology and Engineering Education Association) [10] in 2000 stated that Technology Education is a study covering human capabilities to revolutionize the physical world in order to fulfill necessities by maneuvering materials and devices with procedures. Formerly known as Industrial Arts, Technology Education is viewed as a service area of Career and Technical Education. Technology Education expanded its objective from primarily vocational training to general and academic education designed from K-12 and post-secondary education [11]. It also focuses on the study of technology as a means of developing technological literacy.

Scott and Sarkees [11] further asserted that Technology Education students have numerous concentration areas such as energy, manufacturing and material processing, information processing, and medical technology. They study new technologies like genetic engineering and emerging technologies such as fusion power, which may provide solutions to some of the world's energy supply problems. Students learn that technology can provide tools to solve problems but it can also generate new problems like toxic waste, which is a by-product of chemicals used in manufacturing processes. To summarize, Technology Education was designed to help students better understand the meaning of technology, the creation of technology, and its societal impact. With this philosophy, Technology Education programs should be designed from key component serving as the programs' foundations.

According to ITEEA [10], Technology Education is problem-based learning utilizing technology, mathematics, and science principles. ITEEA further provided a list of what Technology Education concepts involve:

- Designing, developing, and utilizing technological systems;
- Open-ended, problem-based design activities;

- Cognitive, manipulative, and effective learning strategies;
- Applying technological knowledge and processes to real world experiences using up-to-date resources; and,
- Working individually as well as in a team to solve problems.

However, Scott and Sarkees [11] affirmed that colleges and universities are working with state departments of education and local school administrators to provide pre-service and in-service training essential in preparing or upgrading teachers. Teachers will enhance proficiencies needed to create a curriculum based on the ITEEA Standards for Technology Literacy improving technology literacy for all students. Although the ITEEA standards are effective for the academic development of U.S. students and teachers, the evaluation of international Technology Education programs is vital in encouraging global collaborations and workforce development [10], [11]. The following research identifies the progression of Technology Education programs in South Africa.

Technology Education in South Africa

In 1994, the democratic government of South Africa had a priority to fundamentally reconstruct their education system. This priority was at least partly based on the government's commitment to a unified and integrated system of Education and Training [12]. As argued by Christie [13], the integration of education and training seeks to promote skilled, versatile workers with problem-solving abilities and a range of competencies, who will cope with new technologies and work patterns. This radical educational reform was important because it signaled a desire to move away from the educational assumptions of the past through which class and racial divisions and prejudices were reflected in the school /training curriculum. The subsequent reforms in the South African educational system included the replacement of apartheid education policies by Curriculum 2005 (C2005) in 1996; the review and the replacement of C2005 by the Revised National Curriculum Statement (RNCS) in 2000; and the replacement of the RNCS by the Curriculum and Assessment Policy Statement (CAPS) in 2011. These reforms have, however, taken on somewhat contradictory trajectories, as is especially reflected in the shift from C2005 to the RNCS and CAPS, which had important consequences for the goal of an integrated system of education and training.

The introduction of Technology Education as a learning area in the South African General Education and Training (GET) curriculum in 1996 was the result of an extensive development process, which started with the proposal and recommendations made by the Education Renewal Strategy (ERS) and the Walters Report. The discussion document, *A Curriculum Model for Education in South Africa (CUMSA)* [14], released by the Department of National Education (DNE) in 1991, proposed that Technology Education be offered for the first nine years of pre-tertiary education (GET phase) as a compulsory subject, and for the last three years (FET phase) as an optional subject, on the basis that Technology Education would provide education appropriate to the needs of learners and promote a positive societal inpact leading to economic empowerment (Ankiewicz, 1993) [15]. The CUMSA document defined technology along the lines of the sentiments captured in the rationale for the introduction of technology into the GET phase, stating that technology involves humankind's purposeful understanding and inventive use of knowledge and skills with regard to products and procedures geared towards better environmental control [14]. The proposed Curriculum Model for South Africa viewed the introduction of technology as a mechanism through which the curriculum would be made more relevant and supportive of a growing industrial society. It is important to consider that after 1991 there were two initiatives working in parallel to research and make recommendations for the development of a future curriculum.

On the one hand, there was the Walters Report, the related CUMSA proposal, and the working groups that grew out of them, driven by the previous government. In this perspective, technology was, at first, proposed as a pre-vocational subject. The working group for technology that emanated from this initiative, however, soon came to recognize that other countries saw technology contributing to the general education of all children—without any specific vocational label. Their view of technology, therefore, became more closely aligned to the post-1994 positions of Young and Kraak [12] and Christie [13] mentioned above.

After 1994, a national task team called Technology 2005 (T2005) was appointed. It is within the context of the two aforementioned initiatives that the Technology 2005 project should be understood. By the end of 1994, representatives from a number of stakeholder groups (Universities/ Technikons; NGO's; Education Departments; the HSRC; the ANC working group on Science and Technology, etc.) had been working for about a year under the Chairmanship of Barend Wessels of the Free State Education Department to develop a common proposal in terms of which a new subject, technology, might be defined. In December, 1994, this group approached the Committee of Heads of Education Departments (HEDCOM) to appoint a four-member National Task Team to drive this process, with the specific goal of working with provincial teams to develop a proposed technology curriculum for South African (Grade 1 to 9) classes.

After the new curriculum (Curriculum 2005) was introduced in 1996, the aim of the Technology 2005 task team was changed to include the following:

- Develop and pilot teach learning materials in three provinces. (This pilot was evaluated by the National Research Foundation in 1998);
- Train provincial support staff and support the implementation of technology as part of Curriculum 2005;
- Develop PRESET and INSET teacher education programs; and,
- Retrain lecturers from 41 Colleges of Education.

This work was undertaken between 1996 and March, 2000. In 1999, the provincial pilots coordinated by Technology 2005 in three provinces (KwaZulu-Natal, Gauteng, and Western Cape) were evaluated by the Foundation for Research Development (FRD)–now the National Research Foundation (NRF) [15]. The following comment is illustrative:

> Teachers' enthusiasm for and dedication to technology is one of the most consistent and impressive findings from this evaluation. The positive attitude of teachers was fed, in part, by the enthusiasm of their learners. Most teachers indicated that they would like to continue Technology. More than that, many seemed pleased to be able to break out of the old modes of teaching and reconceptualise their notions of what it means to be a teacher/ facilitator. Technology was an introduction to OBE -style teaching for most teachers, who found this approach to be a positive experience, and one that often gained the attention and recognition of their peers. Most teachers thus commented that they had benefited both professionally and personally from their participation in the project. (pp.157-158)

The T2005 National Task Team concluded its work in March, 2000, after which the provinces implemented the new curriculum (and the technology discipline) without any further national support or collaboration. In the five years that elapsed between the publication of the CUMSA document and the 1996 National Curriculum, the CUMSA rationale for including technology was challenged and debated. International initiatives in curriculum change during that period, and a growing belief that the study of technology should be valued for its intrinsic educational rather than its vocational importance, resulted in important changes to the CUMSA model. The model of Technology Education, which emerged in the 1996 National Curriculum, consequently placed less emphasis on the vocational merits of the Learning Area, although it recognized its potential to provide learners with maximum flexibility and adaptability in their future employment and other aspects of life. The technology discipline defined in the 1996 National Curriculum was aimed at ensuring that learners met most, if not all, of the Critical Outcomes that defined national priorities for Education and Training [16].

> It is this potential of Technology Education to act as leverage for human resource development that led to the controversial decision to retain Technology in the curriculum when the Chisholm Commission, appointed by Minister Kader Asmal in February 2000 to review C2005, had recommended that it be scrapped. The Chisholm commission made recommendations which advocated that C2005 be replaced by the National Curriculum Statement (NCS), while retaining strong support for the principles of outcomes-based education. (p.18)

The National Curriculum Statement, which came into effect in 2002, replaced and strengthened C2005 by restructuring its design features, simplifying its language, aligning the curriculum and assessment, and improving provisions for teacher orientation and preparation, learner support materials and provincial funding [17].

As a result of problems in implementation, the NCS, like C2005, was reviewed and replaced by a single comprehensive Curriculum and Assessment Policy (CAPS) document, which came into effect in January, 2012. It is debatable as to whether the CAPS improved the technology curriculum. There is a lot of evidence that the Senior Phase CAPS Technology program attempts to cover too much ground in a very limited time, something that is likely to lead the next set of reviewers to again conclude that technology is too difficult to implement. It also signals a total departure from the C2005 assumption that teachers should be active participants in curriculum development. This means that the weakest teachers will find support in the curriculum, but the most innovative will be frustrated and restricted in their attempts to teach.

The change from C2005 to NCS and now to CAPS clearly indicates the government's willingness to address what has been perceived as a crisis in the implementation of the curriculum. According to CAPS, the content of Natural Sciences and some aspects of technology have been integrated into the Intermediate Phase to ensure a smooth transition between these subjects and to allow learners and teachers to experience the interconnectedness of the Natural Sciences and technology [18]. The last two reviews of the curriculum have signaled a steady return to the models and values of the pre-democracy curriculum. The early commitment to an integrated education and training system is no longer evident. The strictly prescribed form of the CAPS curriculum is less open to teacher mediation and interpretation than even pre-democracy syllabi—and, in the FET curriculum, the technology subjects were slowly taking the form of the pre-1994 technical subjects—Technica Civil, Technica Mechanical, and Technica Electrical. This has some similarities to Technology Education in the U.S.

Problem Statement

There appears to be a lack of comparison between Technology Education programs in the U.S. and Technology Education programs in other countries. Nevertheless, it is essential that student perceptions of Technology Education programs be taken into consideration in order to further enhance academic programs and workforce preparation.

Purpose of the Study

The purpose of this pilot study was to evaluate 1) student attitudes toward Technology Education programs in the U.S and South Africa, and 2) how Technology Education students in the U.S.—enrolled in the Jackson State University Technology Education Master's Degree program—and Technology Education students in South Africa—enrolled in the University of Kwa-Zulu Natal's Honors and 2nd- and 3rd-year Technology Education Bachelor's Degree program—believed that their programs were preparing them for a global workforce. The goal of the research project was to determine if academic level (graduate or undergraduate) and method of instruction (i.e., traditional, hybrid, or online) influences student attitudes and career aspirations.

The following research questions guided this study:

1. What are students' academic experiences (i.e., courses taken, instructional platforms, and use of technological course material)?
2. What are Technology Education students' attitudes about the subject, and have courses helped influence the understanding of Technology Education and technology?
3. What are the students' career aspirations, and is Technology Education aiding in their preparation?

Description of the Subject Population

The graduate students were enrolled in the Technical Education (TE 511) elective course in the Technology Education Master's Degree program at Jackson State University (JSU) in the U.S. There were a total of 14 students in this course. The undergraduate students were enrolled in the Independent Research Course Module (EDTE732) in the Honour's Technology Education undergraduate program at the University of Kwa-Zulu Natal—Durban, South Africa. There were a total of 10 students in this course. This Technology Education program is in the School of Education under the College of Humanities. There were a grand total of 24 students who were to complete the survey.

Methodology

Descriptive research was used to investigate data from 24 graduate and undergraduate students enrolled in one Technology Education course at JSU and UKZN. The Technology Education professors of TE 511 and EDTE732 collaborated to develop a 10-question survey. The survey targeted four areas: 1) demographic information (i.e., age, nationality, and academic level); 2) students' attitudes about Technology Education and technology; 3) career aspirations; and, 4) experiences (i.e., courses taken, instructional platform, and use of technological course material. These areas directed the research questions.

The survey was posted online with the link being sent via email to students with a request to complete it. There were several follow-up reminders sent to students at the end of the semester requesting that they complete the survey. Since this was a pilot study, there was a response rate of 46% (N=11).

Results

Demographic Results

All 11 respondents completed the demographic information revealing age, nationality, and academic level (see Tables 1-3).

Table 1. Age

Age	Number (N)	Percentage (%)
18-21	0	0%
22-27	3	27%
28-32	3	27%
Over 33	5	46%

Research question #1 sought to investigate the students' academic experiences (i.e., courses taken, instructional platforms, and use of technological course material). Responses were collected to identify the number of courses students had taken in their respective Technology Education programs as of spring, 2013. It was revealed that the 11 respondents had varying exposure to the numbers of courses they had taken. Sixty-four percent (N=7) of the respondents had limited exposure, having taken no more than two Technology Education courses. Thirty-six percent (N=4) of the respondents had four or more Technology Education courses (see Table 4).

Table 2. Nationality

Nationality	Number (N)	Percentage (%)
South African	3	27%
American	8	73%
Total	11	100% (of 46% response rate)

Table 3. Academic Level

Nationality	Number (N)	Percentage (%)
Graduate	3	27%
Undergraduate	8	73%
Total	11	100% (of 46% response rate)

Table 4. Technology Education Courses Taken

Number of Courses	Number (N)	Percentage
1 Course	3	27%
2 Courses	4	37%
3 Courses	0	0%
4 Courses	1	09%
5 ≤ Courses	3	27%

Respondents did have access to the various instructional platforms (i.e., traditional face-to-face lectures; hybrid face-to-face and online lectures; online; or, all of the above. Sixty-four percent (N=7) of the respondents indicated having had the traditional lecture platform; 46% (N=5) had the hybrid platform; and 0% (N=0) indicated expose to complete online courses only; however, 18% (N=2) specified exposure to all platforms (see Figure 1).

Furthermore, respondents were asked about utilization of technological course materials (e.g., power point presentations, course readings, or links to subject-related links to websites). Again, respondents indicated varying exposure and utilization of these course materials. Regarding the frequency of utilization of technological course, nine respondents replied, while two omitted this question. Eleven percent (N=1) indicated two to three times a semester; 0% (N=0) indicated once a month; 11% (N=1) indicated two to three times a month; 22% (N=2) indicated one time a week; and, 56% (N=5) indicated two to three times a week (see Figure 2).

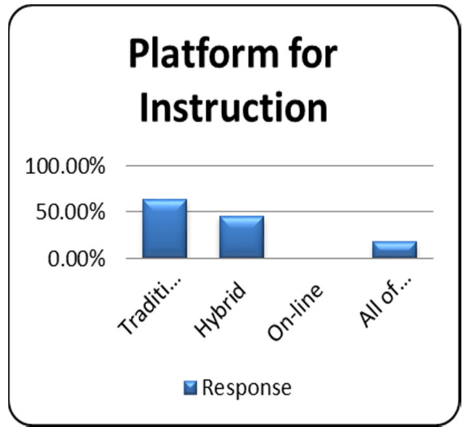

Figure 1. Platform for Instruction

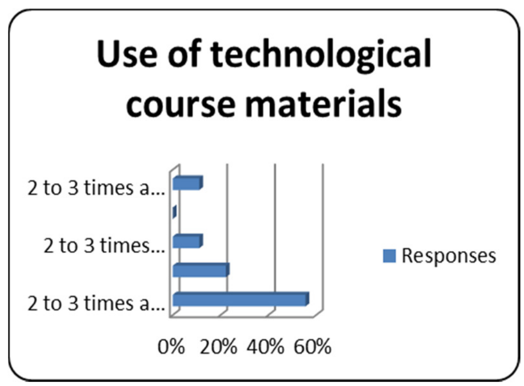

Figure 2. Use of Technological Course Materials

Student Attitudes

When asked about their attitudes towards technology, Technology Education, and courses taken, nine of the 11 respondents completed these questions and two omitted these questions. This served as the premise for research question #2. When asked if the Technology Education courses taken had influenced their understanding of technology and Technology Education, all nine said yes and explained how the courses influenced them with the following comments:

- Exposure to different contents of technology from other counties.
- I have learned about the design process and how to engage with articles in technology among many other things.
- I have become more aware of products, wastage, architecture, structures, use and manufacture of materials.
- I had no previous training in teaching, and I had very little understanding of what Technology Education entailed.
- Everyone Professor X teaches…this professor gives a clear understanding.
- Computer Servicing Lab taught me how to install operating systems onto PC's, how to remove viruses, how to clean out the system, and how to diagnose and repair computer problems for my PC.
- I now know that there is a difference in the two. I understand my field a bit more and I'm more excited about completion of the program.

Career Aspirations

Students were asked about their career aspirations and if their experience in Technology Education had guided their aspirations. The students were asked if the Technology Education programs were preparing them for pursuits. This was the premise of research question #3. Again, nine responded and two omitted these questions. Two of the nine respondents stated that they desired to pursue doctoral degrees and four indicated an interest in becoming professors or instructors.

The remaining respondents stated the following:

- To become a computer science professor, business owner, and minister. Currently, I teach music to the adult and children choir and I produce music for birthdays, personal use, churches, and weddings. Yes, the Technology Ed. program is preparing me to become a prospective professor in the computer science field.
- I aspire to grow and excel in my current work environment. I do believe the program will help me to achieve my goals.
- To be in technology, because I love technology—it's nothing like it!

When asked if their career goals had changed since enrolling in the Technology Education programs, five indicated that their career goals had not changed, because they were currently in technology disciplines or utilizing technology in their daily work tasks. Four respondents yes and provided the following explanations:

- I hope to become a full time lecturer in the future.
- I'm looking for more jobs in Technology Education
- I am more focused, and I know the possibilities that I have. I'm ready to finish the program and jump into my career.
- My perception has been shaped for good.

Lastly, respondents were asked if their career aspirations had changed since enrollment. Four respondents said no and listed the following reasons:

- No.
- I am still pursuing my dreams.
- I still want to lecture Interior Design, but learning about Technology Education has made me think about the possibilities of teaching yonder children rather than only at a tertiary institution.
- My passion has been the same since my sophomore year in college.

Five respondents said yes and listed the following reasons:

- Yes, for good.
- As above, I would like to study further in the field.
- Same as above, I would like to be a lecturer in the future.
- I'm looking for more jobs in Technology Education.
- I am more focused, and I know the possibilities that I have. I'm ready to finish the program and jump into my career.

Discussion

This study revealed findings that will encourage more in-depth evaluation of Technology Education programs and course enhancement in the JSU and UKZN programs. According to Boser et al. [19], it is reasonable that students having a positive experience in a Technology Education program will develop a positive attitude towards technology. The authors further contended that such positive experiences would cause students to pursue technological careers and become more interested in studying about technology. By participating in Technology Education programs, students will become more technology literate. Alexious-Ray [20] affirmed that attitudes toward technology use within the school setting are important. This study revealed that all respondents exhibited a positive attitude toward their respective Technology Education programs and the use of technology. They further suggested that the utilization of technological course materials encouraged more interactive collaboration between students and teachers. In addition, it provides a basis for different teaching and learning styles that are offered by increased technology usage. The findings from this study revealed that all respondents used technological course materials; however, 56% indicated that they used technological course materials two to three times a week. One respondent stated that his Technology Education professor made the subject matter clear and easy to understand. Regarding teaching and learning styles identified in this study, all respondents indicated having had experiences with all forms for instructional platforms (i.e., traditional, hybrid, online, and all types listed). Seven respondents indicated having had a traditional lecture platform; five had the hybrid platform; and, none indicated exposure to complete online courses only; two students, however, did specify exposure to all platforms of instruction.

Considering career aspirations, the findings revealed that two students wanted to pursue a doctoral degree. Other responses acknowledged that all students wanted to incorporate technology in diverse career fields—from education to ministry. Therefore, technology serves as a major part of the students' educational and career aspirations, and Technology Education has helped to further cultivate their knowledge of this application.

Conclusion

This study examined the attitudes and career aspirations of Technology Education degree program students. This study also identified how Technology Education students viewed their academic programs, based on their experiences with courses, instructional platforms, and technology usage. Furthermore, students were asked to describe their career aspirations and indicate if their respective Technology Education programs were preparing them in their career aspirations. According to Buck et al. [21] technology is being integrated into every subject area, and proper training must be relayed to students in order to encourage globalization and mobility. Staying abreast of the latest technologies and trends is essential for preparing students for further academic pursuits and the contemporary workforce. Technology Education serves as this medium. Technology Education builds on technological literacy; however, technology has transcended to global arenas with an increased need for international academic program development.

The review of a Technology Education graduate course at JSU and an undergraduate course at UKZN will help to promote more research and enhanced Technology Education program development. Since technology is needed in every arena and on every academic level, there is a need for more competent educators to facilitate Technology Education. Most students indicated that they wished to become an instructor or professor; this will assist in keeping the legacy of Technology Education on-going with the incorporation of global mobility and collaborations.

Recommendation for Further Research

Further research should be conducted to include the overall enrollment in the Graduate Technology Education program at Jackson State University and the undergraduate Technology Education program at the University of Kwa-Zulu Natal. This will assist in securing more information regarding the attitudes and aspirations of the larger populations. In addition, the larger populations will help in making a meaningful comparison and contrast of the JSU Technology Education graduate and the UKZN undergraduate students, which will render continued program improvements. Further studies should include questions investigating why U.S. and South African students have different experiences in Technology Education programs and how their careers might differ after program completion. In addition, gender studies should be done in order to determine why there is a higher proportion of one gender entering Technology Education programs.

Acknowledgements

This work was supported in part by the National Science Foundation (under grant HRD-1008708). Any opinions, findings, and conclusions or recommendations are those of the authors and do not necessarily reflect the views of NSF.

Special thanks to Dr. Asheena Singh Pillay and the University of Kwa-Zulu Natal's Honors and 2nd- 3rd-year Technology Education Bachelor's Degree program students (EDTE704) and the spring, 2013, Technology Education Master's Degree students (TE 511). In addition, special thanks to Ms. Arlisa Thomas, a Technology Education graduate student at Jackson State University (summer, 2014, Master's Degree Graduate).

References

[1] The Technology Education Lab (2013). What is Technology Education? Retrieved from http://www.techedlab.com/define.html on June 11, 2014.

[2] Al-Rodhan, N. R. F., & Stoudmann, G. (2006). Definitions of Globalization: Comprehensive Overview and a Proposed Definition. *Geneva Centre for Security Policy*. Retrieved from http://www.gcsp.ch/About-Us-Qui-sommes-nous/Staff/Staff/Dr-Nayef-AL-RODHAN/Publications/Books/Faculty-Publications/Books-and-Edited-Volumes/Pillars-of-Globalization.

[3] Misra, S., & Baipai, A. (2010). Implications of globalization on education. *Social Science Research Net-*

work. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id =1800740 on May 31, 2013.

[4] Wildavsky, B. (2010). No barriers to free trade in minds. *The Wall Street Journal*. Retrieved from http://www.relooney.info/0_New_7233.pdf on June 27, 2013.

[5] Caliguri, P., Lepak, D., & Bonache, J. (2010). *Managing the global workforce*. Chichester, West Sussex (U. K.): John Wiley & Sons, Ltd.

[6] HUD Pages. (2011). *Occupational mobility: definition and characteristics*. Retrieved from http:// mreslam206.hubpages.com/hub/ Occupationalmobility on June 15, 2013.

[7] United States Census Bureau (n. d.). Retrieved from http://www.census.gov/hhes/migration/ on June 20, 2013.

[8] Harvard College. (2013). *Population mobility: migration in a global economy*. Retrieved from http:// www.hsph.harvard.edu/population-development/ research-focal-areas/population-mobility-migration-in-a-global-economy/.

[9] Kim, Y. Y. (2010). Female individualization?: Transnational mobility and media consumption of Asian women. *Media, Culture and Society*, *32*(1), 25-43. doi: 10.1177/0163443709350096.

[10] ITEEA. (2011). What is Technology and Engineering Education? Retrieved from http://www.iteea.org/ AboutITEEA/about.htm on July 24, 2013.

[11] Scott, J. L., & Sarkees-Wircenski, M. (2008). *Overview of career and technical education*. (4th ed.). Homewood, ILL. American Technical Publishers, Inc.

[12] Young, M., & Kraak, A. (2001). *Introduction*. In A. Kraak & Young (Eds.), *Education in Retrospect: Policy and Implementation Since 1990* (pp.1-16). HSRC Press.

[13] Christie, P. (1996b). Globalization and the curriculum: proposals for the integration of education and training in South Africa. *International Journal of Educational Development, 16* (4), 407–416.

[14] South Africa. Department of National Education (DNE) (1991). *A curriculum model for education in South Africa (CUMSA)*. Pretoria: Committee of Heads of Education Departments.

[15] Ankiewicz, P. J. (1995). The planning of Technology Education for South African schools. *International Journal of Technology and Design Education*, *5*(3), 245-254.

[16] Mouton, J., Tapp, J., Luthuli, D., & Rogan, J. (1999). *Technology 2005: A National Implementation Evaluation Study*. Stellenbosch: CENIS.

[17] Chisholm, L., *et al.* (2000). *A South African Curriculum for the Twenty First Century: Report of the Review Committee on Curriculum 2005*, Department of Education, Pretoria.

[18] Chisholm, L. (2005). The making of South Africa's National Curriculum Statement. *Journal of Curriculum Studies, 37*(2), 193-208.

[19] Department of Basic Education (DoBE). (2011a). *National Curriculum Statement (NCS): Curriculum and Assessment Policy Statement (CAPS) Grade 4-6 Natural Science and Technology*. Pretoria: Government Press.

[20] Boser, R. A., Palmer, J. D., & Daugherty, M. K. (1998). Students' attitudes toward technology in selected technology education programs. *Journal of Technology Education, 10*(1), 4-19.

[21] Alexious-Ray, J., Wilson, E., Wright, V., & Peirano, A. (2010). Changing Instructional Practice: The Impact on Technology Integration on Students, Parents, and School Personnel. *Electronic Journal for the Integration of Technology in Education, 2*(2), 58-80.

[22] Buck, J. L., Conley, S., Harris, B., & McInnis, E. (2012). Service learning: bridging the gap classroom theory and application for technology students. *Technology Interface International Journal, 12*(2), 66-72.

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A COMPARISON OF ACHIEVEMENT RESULTING FROM LEARNING ELECTRONICS CONCEPTS BY COMPUTER SIMULATION VERSUS TRADITIONAL LABORATORY INSTRUCTION

Saeid Moslehpour, University of Hartford; Kouroush Jenab, Embry Riddle Aeronautical University; Kathryn Young, University of Hartford

Abstract

The purpose of this study was to increase student knowledge about passive-device electronics. This study aimed at comparing student achievement resulting from learning electronics concepts by computer simulation with traditional laboratory instruction. A statistical analysis was performed on the results from a questionnaire given to two groups of students. Each group was exposed to the same method that covered electronic topics. The questionnaire was made up of multiple-choice questions and given to the participants. Findings from several questions yielded α=0.05. The results revealed that computer simulation should be applied to complex topics; however, this learning process should begin with beginning courses. Also, it was concluded that more time is needed for students lacking computer literacy. Overall, using computer simulation in electronics education and related areas is recommended.

Introduction

In recent years, large numbers of computers have infiltrated the educational system and have been crucial for meeting many instructional needs. As a result of this infiltration, it has become necessary to evaluate how effective computer simulation is as an instructional method or strategy. Much research has been focused on the effect of computer simulation on many areas. However, with regards to education, there is no consensus as to whether computer simulation should be implemented in the classroom. Perhaps because of this uncertainty about the use of computer simulation, especially in entry-level courses, more specialized studies should be conducted.

There is evidence that many industries are using computer simulation. Large corporations such as IBM, Apple, and DEC have already experienced the advantage of design with computer simulation. Many companies have adopted the simulation procedure. The complexity of electronic circuitry has made computer simulation a necessity in modern electronics industries. In fact, several universities such as the Massachusetts Institute of Technology, the University of California at Berkeley, and Iowa State University are using computer simulation as a tool for designing electronic circuitry.

Despite the fact that studies have been conducted on computer simulation, the effectiveness of it varies from population to population and study to study; therefore, more studies with specific populations are needed. This research study compared two groups of students who were exposed to computer simulation at two different institutions—Iowa State University and the University of Hartford. The central purpose of this study was to determine whether computer simulation should be applied in classes covering the beginning level of electronics in order to achieve higher student achievement scores and mastery of skills.

Statement of the Problem

This study was designed to evaluate and compare the effectiveness of computer simulation techniques in teaching basic electronic circuitry versus the traditional method involving passive components (resistors, capacitors, inductors, etc.) to freshmen college students. The objectives of this study were:

- Compare the level of achievement between a group of college students who learned basic electronics circuitry (passive components) using laboratory experiments and a second group of college students who learned the same concepts using laboratory experiments and computer simulation.
- Determine the effectiveness of using computer simulation as opposed to using traditional laboratory experiments employing passive electronic circuitry.
- Assess the instructional methods and their effectiveness in teaching passive electronic circuitry.
- Evaluate the effectiveness of each instructional method by analyzing the results of post tests given at the end of each topic.
- Assess the effectiveness of each instructional method by analyzing the results of the tests given in the middle and at the end of each topic covered in the course.

- Evaluate the effectiveness of instructional methods by analyzing the results of difficult items in all post-tests.

The students participating in this study were enrolled in the spring and fall semesters of 1992. The control and experimental groups were enrolled in the fall of 2011. In each case, the same software—albeit a different version—was used. This study was limited to the topics listed below during the thirty weeks of the experiment:

1. Ohm's law and power
2. Series circuits
3. Parallel circuits
4. Series-parallel (combination) circuits
5. Alternating current and voltages
6. Capacitors
7. Inductors
8. Transformers
9. Frequency Response of RC circuits
10. Frequency Response of RL circuits
11. Frequency Response of RLC circuits
12. Pulse response of RC and RL circuits

Literature Review

Science, Technology, Engineering, and Mathematics (STEM) programs have been studied to identify the risk and the task force (i.e., Technology, Performance, and Class preparation) [1]. Wilson [2] studied a method of data collection called a focus group. This method is suitable for market research because it can identify focus groups and the way they can be used. Also, some of the practical and theoretical implications for incorporating focus groups in the design of educational research projects, paying particular attention to issues of data generation, were discussed. Considering technical and transparency aspects in STEM programs, a fuzzy complexity model for educational programs was developed [3].

Distance learning has become an essential part of the educational system, especially in higher education institutions where students are attempting to complete undergraduate and graduate programs. Competing responsibilities like work, family, military station, illness, or anything else that interferes with traditional education make distance learning a popular mode of instruction [4]. Working on a learning task through the use of a computer or computer software can be an effective stimulus for learning [5]. However, educators feel that an indispensable part of distance learning is the interaction it engages students to participate in [6].

The use of computer simulations can be an excellent way to provide students with interactive practice [7]. Computer-based learning (CBL) can be effective when the program uses guided discovery versus unguided discovery. Veenman et al. [8] showed that students using guided discovery programs have better working methods and better scores on qualitative posttests of the material. Also, in order to be effective, CBL must be more than just button clicking; there has to be an element of reasoning, creativity, and construction in order to keep the learning focused and the students interested [9].

While software simulations are not meant to entirely replace lectures, they can offer a variety of benefits [10]. When the software is designed appropriately, students often experience an increase in comprehension and retention of the material, as well as an ease of use, learning, and a positive attitude towards the computer teaching tool [11], [12]. A study examining the difficulties that the Department of Mathematics and Computing at Central Queensland University faced when providing distance education to its students outlined five places where problems can manifest and attempted to solve them. These five areas were the characteristics of students, academics, the institution, the tools used to convey learning materials, and the subject of computing. Results showed that with a little flexibility from all parties, a lot of these problems can be remedied [13]. CBL can be an effective way to teach material to the deaf and hard-of hearing as well. Studies show high satisfaction, ease of use, and comprehension [14]. CBL can also significantly reduce time spent learning the material without affecting learning, which can benefit both students and educators [15]. Furthermore, CBL can also expose students to situations that would otherwise be too expensive or possibly harmful to allow without computer simulation [16], [17].

CBL's effectiveness and benefits to students and staff are excellent reasons to continue to experiment with computer software as a teaching tool. PSpice is a program used within engineering departments to help students learn better. Students from a class in 2010-2011 and from a class in 2012 used the software throughout the course and then completed a questionnaire about their learning experience. The purpose of this study was to determine the students' attitudes toward PSpice's effectiveness, ease of use, and attractiveness in relation to learning material.

Significant research has been conducted to date employing computer simulation; however, more studies need to be conducted in order to clarify the effect of computer simulation in teaching diverse subjects in a variety of learning situations. This is true especially in beginning-level courses taught in colleges and universities. It should also be noted that the majority of research has been conducted over short periods of time—two to eight weeks. Not many studies have been conducted over a longer period of time. This topic of computer simulation has been identified as being of significance to teachers in providing them with the skills and knowledge necessary to effectively teach lessons in freshman electronic courses in college and universities.

Data Analysis

This study was designed to compare student achievement resulting from learning electronics concepts by computer simulation. Two groups of college students participated in this study over an academic semester. Each group received lectures and laboratory instruction for each topic. The results reveal that computer simulation should be applied to complex topics; however, this learning process should begin with beginning courses. Also, it can be concluded that students lacking computer knowledge need more time. Overall, using computer simulation in industrial/electronics technology and related areas is recommended.

Besides the demographics, the following questionnaire was given to the two groups of students:

10. Working with PSpice was challenging.
11. I understood the assignments related to PSpice.
12. I felt alone and isolated when working with PSpice.
13. I was usually attempting get the PSpice assignments done rather than trying to learn the materials.
14. PSpice software should be used on all electronic courses taught in college/university classes.
15. PSpice software could be used more effectively to facilitate the learning process.
16. PSpice software made electronics more interesting.
17. I spent more time trying to learn how to operate the hardware (computer) rather than understanding the materials.
18. I performed better when I worked individually on PSpice assignments.
19. Assignments were too mechanical using PSpice.
20. PSpice gave me a better graphical understanding of the waveforms (transit analysis using the probe).
21. Working with PSpice was too time consuming.
22. Additional instruction is needed on how to operate PSpice.
23. PSpice should be used in:
24. Using PSpice is a waste of time on elementary circuits.
25. Using the PSpice is beneficial on more complicated circuits.
26. Using PSpice distracted me from concentrating on the materials covered in the course.
27. The personnel monitoring the computer laboratory were helpful to assist my questions about PSpice.
28. The computer laboratory equipment (computers, printer, software) were working all the time.
29. PSpice helped me comprehend the information quicker.
30. Using the PSpice software was frustrating.
31. Generally feel frustrated when working with computers.
32. Considering the amount of time I spent on PSpice I feel satisfied with what I have learned.
33. In my view, learning electronics using PSpice is superior to regular laboratory instruction.
34. Using PSpice makes the instruction less personal.
35. I do not believe electronics should be covered in this department.

These conclusions are based on an independent T-Test that was used to compare the average response to each question between the two classes. Data indicated that the differences between classes in response to Questions 19 (p=0.01), 24 (p=0.046), and 27 (p=0.007) were significant; no other questions showed significant differences between classes.

Table 1. Comparisons between Class EL111 and the Class of 1993 Questionnaires

	EL111		2010—2012			
Question	Mean	SD	Mean	SD	t	p
Q10	3.20	1.30	3.67	0.96	-0.95	0.35
Q11	3.00	1.58	2.63	1.18	0.61	0.55
Q12	3.00	1.58	3.00	1.11	0.00	1.00
Q13	3.40	0.55	3.26	1.18	0.43	0.68
Q14	2.80	1.64	2.63	1.25	0.27	0.79
Q15	3.80	0.84	4.00	0.83	-0.49	0.63
Q16	3.00	1.58	2.93	1.14	0.13	0.90
Q17	2.80	0.84	3.11	1.22	-0.54	0.59
Q18	3.00	1.23	2.15	1.06	1.61	0.12
Q19	3.40	0.89	2.41	0.75	2.65	0.01*
Q20	3.00	1.41	3.33	1.30	-0.52	0.61
Q21	3.60	1.14	3.52	1.22	0.14	0.89
Q22	3.40	1.52	4.07	1.07	-1.21	0.23
Q23	3.40	1.51	2.78	1.22	1.01	0.32
Q24	3.40	0.89	2.33	1.07	2.08	.046*
Q25	4.20	0.45	3.81	1.04	0.81	0.43
Q26	2.80	1.03	3.11	0.97	-0.62	0.54
Q27	3.40	1.34	2.07	0.87	2.87	.007*
Q28	2.80	0.83	2.52	1.25	0.48	0.64
Q29	3.40	1.14	2.96	1.05	0.84	0.41
Q30	3.00	1.82	3.74	0.98	-0.80	0.48
Q31	3.00	1.41	1.96	0.71	1.60	0.18
Q32	2.40	1.14	2.74	1.16	-0.60	0.55
Q33	3.00	1.58	2.07	1.11	1.61	0.12
Q34	3.00	1.23	3.00	0.83	0.00	1.00
Q35	2.80	0.84	1.89	0.97	1.96	0.06

*indicate significant values

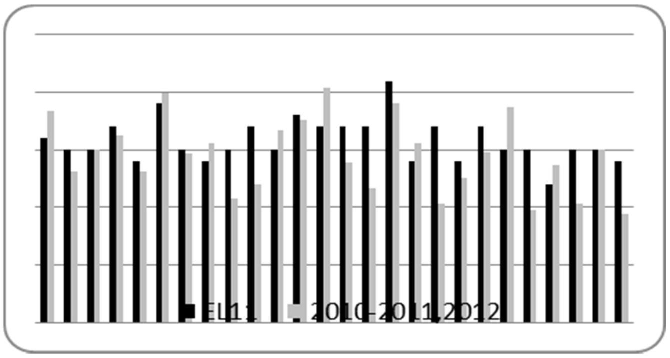

Figure 1. Comparison between Responses of EL111 and the Class of 1993

Conclusion

This study was designed to compare student achievement resulting from learning electronics concepts by computer simulation. The purpose of this study was to enhance student knowledge about the passive-device electronics circuitry. Two groups of college students participated in this study over an academic semester. The majority of research indicates that computer simulation enhances student knowledge of the subject matter. Each group received lectures and laboratory instruction for each topic. Findings indicated that there were some significant differences between the two groups.

The results of this study revealed that computer simulation should be applied to complex circuits, and these circuits should include the topics typically covered in Electronics I and II courses in an Electrical Engineering degree curriculum. However, this learning process should begin with beginning courses such as Circuits I and II. This study also concluded that more time is needed for students who do not have computer literacy. Overall findings were in favor of using computer simulation in electrical and electronic courses and related areas.

References

[1] Khoury, S., Jenab, K., Staub, D., & Rajai, M. (2012). Using database technology to improve STEM student retention: A total quality management approach to early alert and intervention. *Journal of Management Science Letters*, *2*(2), 647-654.

[2] Wilson, V. (1997). Focus groups: a useful qualitative method for educational research? *British Educational Research Journal*, *23*(2), 209-224.

[3] Jenab, K., Khoury, S., & Sarfaraz, A. (2012). Fuzzy complexity model for educational projects. *International Journal of Industrial Engineering and Production Research*, *23*(1), 1-5.

[4] Bates, A. W. (1995). *Technology, Open Learning and Distance Education*. London: Routledge.

[5] Jonassen, D. H., & Driscoll, M. P. (Eds.). (1996). *Learning with technology: Using computers as cognitive tools,* in Handbook of Research for Educational Communications and Technology. New York, Simon and Schuster Macmillan.

[6] Wagner, E. D. (1997). Interactivity: From agents to outcomes. *New Directions for Teaching and Learning, 71*(2), 19-26.

[7] Berge, Z. (2002). Active, Interactive, and Reflective Learning. *The Quarterly Review of Distance Education*, 3(2), 181-190.

[8] Veenman, M. V., Elshout, J. J., & Busato, V. V. (1994). Metacognitive mediation in learning with computer-based simulations. *Computers in Human Behavior*, *10*(1), 93-106.

[9] Woolf, B. P. &. Hall, W. (1995). Multimedia pedagogues: Interactive systems for teaching and learning. *IEEE Multimedia*, *28*(5), 74-80.

[10] Sahin, D. (2006). Computer simulation in science education. Turkish Online Journal of Distance Education, *7*(4), 7.

[11] Brain, S., Dewhurst, D. G., & Williams, A. D. (1999). Evaluation of the usefulness of a computer-based learning program to support student learning in pharmacology. *Research in Learning Technology*, *7* (2), 1-10.

[12] Ruttern, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effect of computer simulation in science education. *Computers and Education*, *50* (1), 136-153.

[13] Jones, D. (1996). Computing by Distance Education: problems and solutions. *ITiCSE '96 Proceedings of the 1st conference on Integrating technology into computer science education*, New York.

[14] Kosec, P., Debevc, M., & Holzinger, A. (2009). Towards equal opportunities in computer engineering education: Design, development and evaluation of videobased e-lectures. *International Journal of Engineering Education*, *25*(4), 763-771.

[15] Gibbons, N., Evans, C., Payne, A., Shah, K., & Griffin, D. K. (2004). Computer simulations improve university instructional laboratories. *A Journal of Life Education*, *16*(1), 84-89.

[16] Granlund, R., Berglund, E., & Eriksson, H. (2000). Designing web-based simulation for learning. *Future Generation Computer Systems*, *17*(2), 171-185.

[17] Kim, H., & Hannafin, M. J. (2011). Developing situated knowledge about teaching with technology via Web-enhanced Case-based activity. *Computers and Education*, *57*(1), 1378-1388.

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The Metallurgical Challenge: A Meaningful Learning Activity

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Abstract

Many engineering and technology programs are structured to allow students to take fundamental math and science classes before core classes in their programs, with the result that all too often students fail to make the connections between theory and actual application. If these connections are not made early in a student's program of study, students may leave programs that they were otherwise well suited for. This case study provides information about a project dealing with the heat treatment of steel, based on the principles of meaningful learning that was successfully implemented in an introductory materials class. Details of this study provided here should allow the project to be modified to suite a variety of technology program areas.

Introduction

All too frequently, engineering and technology programs tend to be structured in a way that fundamental principles are covered before applications. In other words, the first year is composed of basic mathematics and science classes [1], which often are taught outside the engineering departments [2]. And only in the 2^{nd} and 3^{rd} years do students start to get into actual applications. Felder [1] refers to this as the "Trust Me" approach to education, where the student is frequently told that the meaning behind the complex math and science will eventually become clear as they progress through the program. Studies have shown that many engineering students perceive their learning environment as one that fails to motivate them. Oftentimes, this approach results in students feeling as if they are drowning in a sea of theory, and a subsequent loss of direction often leads to a change of majors.

For students to achieve success, learning must be more meaningfully engaging so that they can see the connection between what they are doing and the bigger picture. If these connections are not made, then students often see only individual pieces of a puzzle but not the "big picture." Though good pedagogy alone is not a replacement for lack of content, it is equally as important to consider that a lack of pedagogy can have a negative impact on learning. In the end, a high-quality learning environment demands attention to content, while also studying how people learn.

Creating activities that engage students while maintaining their interest is a challenge that all educators face at some point in their careers. However, the benefits of planned, purposeful activities are that students are provided with rich, meaningful learning experiences. The term meaningful learning, as used by Jonassen [3], suggests that in order for students to learn meaningfully, they must first want to engage in a meaningful task. According to Jonassen, meaningful learning occurs when learners are active, constructive, intentional, and cooperative, while working on authentic tasks. Therefore, creating projects that students will want to do on their own, instead of one they are forced to do, may be the gateway to meaningful student learning.

Need for an Activity

Metallurgy is a complex, technical field that can quickly become confusing to students taking introductory classes. The activity described in this study, referred to as the Metallurgical Challenge, was not designed to serve as a complete treatise on the subject of metallurgy, and was; in fact, only one component of an introductory industrial materials course that covered many other types of materials. It was the intent that students participating in this activity would discover, through experiential learning, the basic elements of heat treating carbon steels and this knowledge, perhaps coupled with the excitement of self-discovery, would allow a better grasp of more complex theories presented later in same course, or for more advanced courses in the future..

The activities for the Metallurgical Challenge are presented in three stages with each stage building on the previous. Throughout the activity, individual stages were deliberately presented using somewhat ambiguous terms in order to foster a true experiential learning experience which required a substantial amount of research and teamwork in order to complete the problems. In addition, for each of the stages, students were required to reflect on what they did using a variety of means.

Importance of Steel

While it would not be appropriate to state that one metal is more important than another, it is safe to assume that steel is by far the most widely used alloy. Steel is used in almost every aspect of our lives from the cars that we drive to the buildings that we work in. In 2014, steel mills around the world have a production capacity of about 1.8 billion tons, with some estimates showing that by 2016 additional mills will increase the capacity by 350 million tons [4]. The popularity of steel as an engineering material cannot be overlooked, and understanding the basic properties of steel is an important part of any engineering or technology curriculum.

Principles of Heat Treatment

Medium- and high-carbon steels can both be heat treated to make them either harder or softer using century-old methods [5]. Understanding how the processes work requires a basic understanding of the properties of steel, which is composed of basically two elements: iron and carbon [6]. Other elements may be present, but for the purposes of this activity they can be overlooked. As the carbon content in steel increases to about .60%, so does the ability to harden the material [6]. Figure 1 illustrates this concept. Therefore, if too much carbon is present, the material becomes very hard and brittle; as the percentage of carbon decreases, so too does its ability to respond to heat treatment.

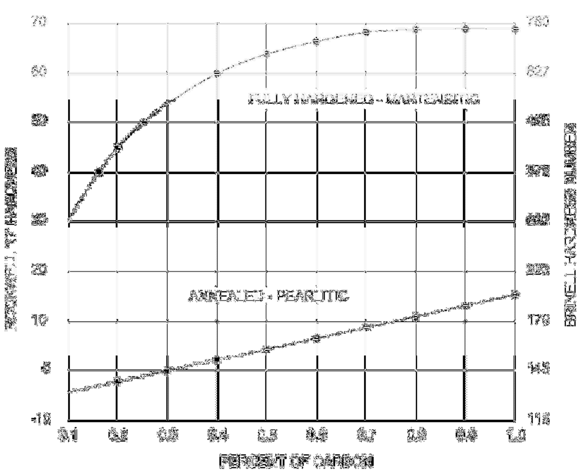

Figure 1. Approximate Impact of Carbon Percentage on Hardness of Carbon Steel in Both Martensitic and Pearlitic Conditions [6]

Thermal Processing

At room temperature, most common steels are composed of a mixture of both cementite and ferrite. Cementite is essentially iron carbide, and ferrite is basically iron. When steel is heated to approximately 1350 °F, the cementite dissolves in the matrix and a phase change occurs, which is referred to as austenite. A phase is a portion of a particular alloy which can be chemically, crystallographically, or physically homogenous throughout [7]. If the material is rapidly cooled, the material produced will have extremely good wear resistance due to its hardness, but it will also be extremely brittle and can be easily broken.

In order to remove some of this brittleness while making the steel tougher, a process called tempering is performed. Tempering involves heating the steel sufficiently to convert some of the martensite to the softer, more ductile, pearlite. The degree to which steel is heated will determine how much martensite is converted back to pearlite and, in this manner, steel can be tailored to suit a wide variety of applications such as a spring, which requires a balance between the two extremes [8].

The Iron-Carbon diagram in Figure 2 graphically illustrates the transformation temperature and how it relates to carbon content. The transformation temperature is also the point at which the carbon steel takes an inner form referred to as austenite—a non-magnetic form of iron which has the ability to dissolve carbon and other alloying elements.

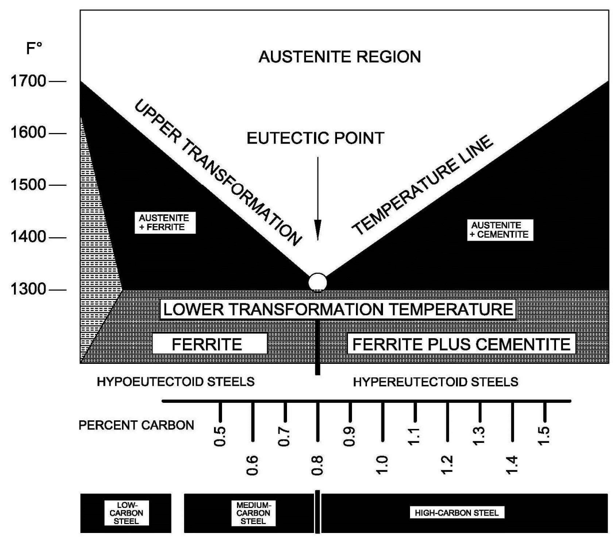

Figure 2. Iron-carbon Phase Diagram

In examining the Iron-Carbon diagram illustrated in Figure 2, the eutectoid point occurs where the upper transformation temperature line, the lower transformation temperature line, and the 0.8% carbon pearlitic lines converge. On either side of the eutectoid point are two black triangular areas that represent the temperature transfer range. As the heat rises, the existing low-temperature structure represented by ferrite, pearlite, cementite, or martensite is transformed to austenite. As the temperature drops, the austenite is transformed into martensite, ferrite, pearlite, or cementite.

Which structure the metal takes is dependent on the speed of the cooling process [9].

The Activity

The individual stages for the Metallurgical Challenge are presented below in chronological order. Following each stage in the activity is a general explanation regarding aspects that were covered and lessons that were learned. The specific learning objectives for this activity were to:

- apply the principles of material science in the solution of technical problems involving ferrous materials;
- describe the phases and changes that occur during various heat treatment processes based on an analysis of photographic documentation and other physical evidence; and,
- explain the relationship between heat treatment and mechanical properties in a reflective report.

Stage 1

1. Select a piece of ½" x .062 rectangular mild steel bar stock and cut to a length of 5".
2. Process the steel strip so that your file will cut a notch about 1/8" deep into one edge, but not the opposing one (see diagram).
3. Process the strip so that the following can be performed:
    a. A file will no longer cut into the strip at any point along its length on either side.
    b. When secured in a vise with one inch exposed on the opposite end from where you had previously notched the strip with your file, a sharp blow from a hammer will result in a clean fracture.

Importance of Carbon

The use of mild steel, in lieu of high-carbon steel, was the main hurdle that students needed to overcome. The importance of carbon content was a concept that was stressed in previous activities and students were aware that the mild steel that was provided to them would not respond well to conventional heat treatment. Though they previously studied the relationship that carbon plays in the ability of steel to respond to heat treatment, having to heat treat a piece of steel that lacked a suitable amount of carbon posed an interesting challenge for them.

Many students looked to the Internet and various forums to arrive at possible solutions. One student group discovered a process for hardening mild steel that involved a complicated brine solution referred to as a super quench; this was attempted, but proved ineffective. Other students decided to use a process called case-hardening that works by adding carbon to the surface of the steel. This was attempted using powdered wood and bone charcoal packed around the part in steel crucibles inverted on a steel carrier, similar to the one illustrated in Figures 3 and 4. This method proved effective for hardening the surface of the steel, but it was found that when attempting to fracture the steel in step 3(b), the steel would simply bend without breaking.

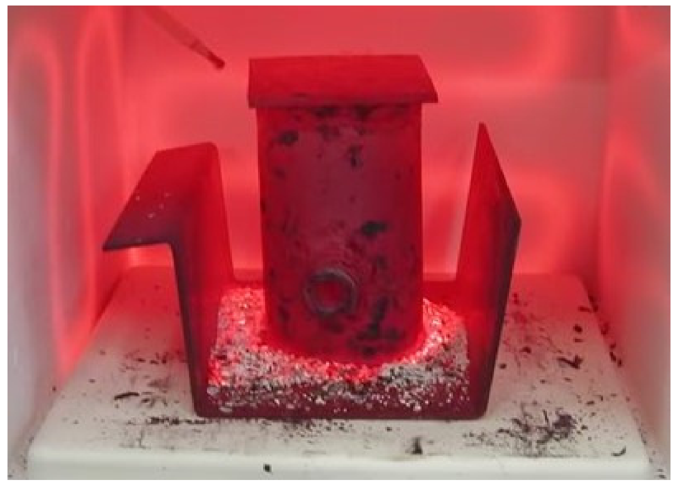

Figure 3. Crucible for Carburizing Parts in Stage 1

Figure 4. Sparks Fly as the Lathe Cutter is Quenched in Stage 2

Despite this setback, some students recognized that they were on the right path, even though the carbon that was added to the part did not penetrate very deeply. Further research showed that higher temperatures and longer soak times would increase the depth of carbon penetration, so this was attempted. One interesting method that was discovered utilized crucibles, such as the one shown in Figure 3, to strategically place several of these in the furnace at the same time, as shown in Figures 5 and 6. Various temperatures were used, with most eventually setting at 1650 °F. As the material was heated in the furnace, the individual crucibles were removed at different times and the test strips hardened, as shown in Figure 5. After a sufficient amount of time had passed, approximately 5½ hours, the test strips were breaking cleanly, as shown in Figure 7. The successful test breaks generally occurred with the samples being in the furnace at the aforementioned temperature for around 5½ hours. One student later found a table similar to the one shown in Figure 8 that illustrated case depths at different time and temperature sequences. Some students mentioned that it would have saved a lot of time if they had found the chart earlier, but they all seemed proud of the fact that the data on the chart validated what they found through experimentation.

Figure 5. Technology Students Heat Treating a Spring in Stage 1

Figure 6. Technology Student Placing Crucible Containing the Lathe Cutter in the Furnace for Carburizing in Stage 1

Figure 7. Observing the Fine Grain Structure in the Steel Test Strip from Stage 1

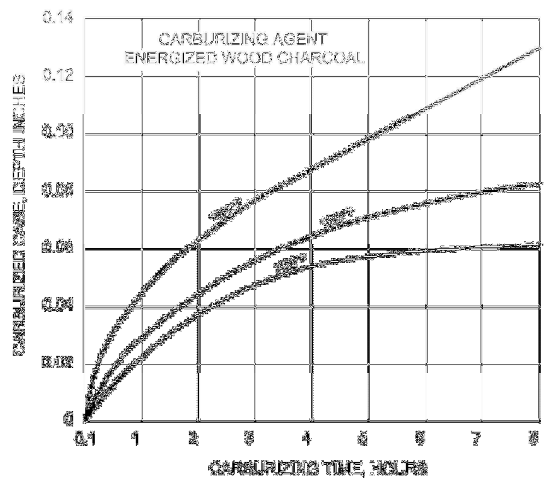

Figure 8. Carburization Rate with Energized Wood Charcoal at Differing Temperatures

Tempering

In addition to learning the impact that carbon plays in the ability of steel to respond to heat treatment, students also learned about the tempering stage. As they observed following the quench, the carbon steel pieces became very brittle and were easy to fracture. This, they learned in other lessons, was due to the sudden cooling that occurred during the austenite stage, which changed the molecular structure to the very brittle martensite. To remove some of the brittleness required heating the steel just enough to change some of the molecular structure to pearlite. By modifying the temperature which controls how much of the martensite is converted to pearlite, students learned that they could control the characteristics of the steel to suit their needs. Figure 9 shows a student tempering the steel test strip using a hand-held propane torch as the heat source, with one half of the test strip submerged in a pan of water to act as a heat barrier. Observations of the temper colors, shown in the finished product in Figure 10, allowed accurate control of the temperature. This process is often referred to as differential tempering and is commonly used by knife makers to keep a very hard cutting edge and a softer, tougher spine, which is desirable in knives that are going to see hard use [9]. Finishing this portion of the project required students to become very comfortable manipulating the steel so that some parts would remain hard while others would be soft enough to easily cut with a hand file.

Figure 9. Technology Student Differentially Tempering Steel Strips in Stage 1

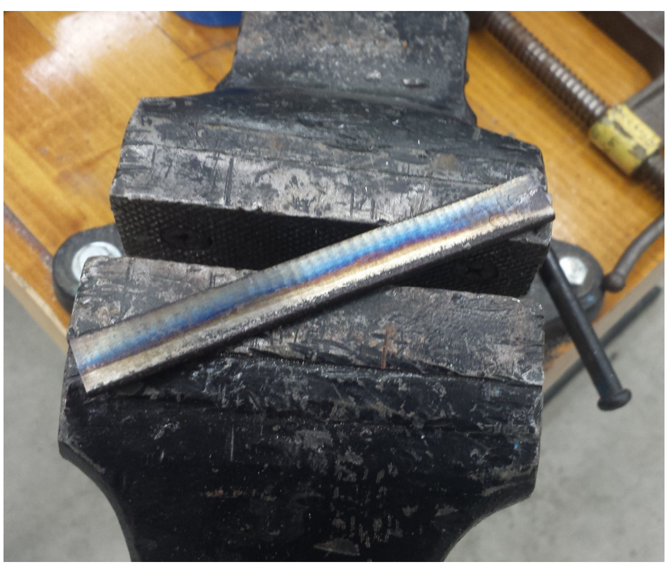

Figure 10. Differentially Heat-treated Test Bar, as Produced in Stage 1

Grain Structure

Observing the grain structure from the point of fracture was another important aspect of the Metallurgical Challenge project. Observations of the steel specimens between groups clearly showed the differences, as can be seen in Figures 7 and 11. Students were asked to photograph the fracture and, since there were several samples from the earlier trial, there were sufficient opportunities to observe the differences between samples. Clearly, some samples exhibited a much coarser grain than others. Most of the groups found that there was some correlation between length of time and temperature and grain size. This was particularly apparent with samples that had been heated at temperatures surpassing 1800 °F for extended periods of time. The sample shown in Figure 10 had been quenched at 1950 °F after four hours in the carburizing compound; this sample exhibited a very course structure.

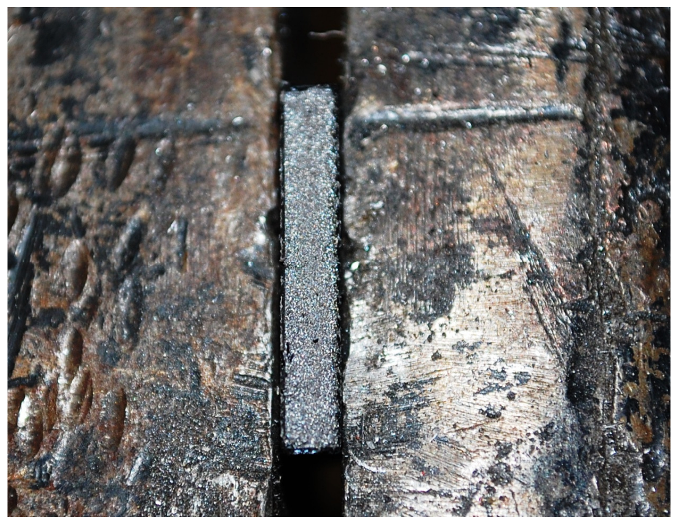

Figure 11. Example of Course Grain Structure in a Test Strip from Stage 1

Stage 1 Summary

Many times in education less is more and, in this instance, the students clearly seemed to benefit from a situation that required more manipulation, experimentation with less detailed instructions, while using the material available at the time. Many traditional heat treatment lab activities use steel with sufficient carbon content to heat treat; and though more convenient for students, finding the correct heat treatment for the steel being used involves little more than finding the proper heat treatment recipe in a machinists handbook. Those who work in industry often find themselves in circumstances that are not picture-perfect, or ideal, and these situations demand a line of thought that is often referred to as “thinking outside the box”. This project provided an authentic representation of this type of experience, which is one of the primary tenants of a meaningful learning experience.

Stage 2

1. Select a piece of ¼” mild steel square stock and cut to 2” in length.
2. Grind a profile appropriate for a right handed lathe bit and answer the following questions.
   a. What possible limitations exist when using a carbon steel lathe bit as opposed to a high-speed steel, or carbide bit?
   b. What are the advantages of a carbon steel lathe bit over a high-speed steel, or carbide bit?
3. Using a piece of .375” diameter mild steel bar stock, use a metal lathe to machine out the profile of the center punch using the right hand lathe bit created in the previous step and provide a response to the following question
   a. What physical properties should a center punch that would be used against annealed mild steel possess?

In this stage, students were required to manufacture two separate tools, a right-hand lathe bit and a center punch. This activity builds upon the knowledge gained in stage 1 and adds the additional challenge of students needing to determine the proper heat treatment process to use for a specific type of tool. Figure 12 shows a completed right-hand lathe cutter. Once again, both the lathe bit and the center punch were to be made from mild steel and both had different functions demanding different heat treat specifications.

Figure 12. Lathe Cutter Produced in Stage 2

Students taking this materials class had already completed an introductory manufacturing process class and were comfortable using the production processing equipment with carbide and high-speed steel tooling. This activity, however, presented the added challenge of requiring students to grind their own tools, learn about cutting tool geometry, and understand how to use a heat treatment process for a specified application. Students, prior to this activity, had experience with carburization. Therefore, it was not surprising that one group simply carburized the square steel blanks and attempted to grind them following this process, with the result that they ground off most of the carbon layer, effectively preventing the tool from being heat treated. A second group found that by pre-shaping the bits before the carburizing process, they could harden and temper the bits following the carburizing stage and complete the final honing operation without removing too much material. A third group used a deep carburizing process to penetrate the entire cross-section of the lathe bit.

In the second operation, where students machined out the center punch shown in Figures 13–15, most seemed surprised at how well the cutters actually worked. The lathe bit that appeared to work the best were those that had a relatively shallow case-hardened surface with no post-tempering operation. Students who achieved the desired outcome correctly reasoned that the softer core of the low-carbon tool steel would strengthen the cutter to the degree that there was little need to soften the cutting edge, which would have reduced its wear resistance.

At the other extreme, the groups that attempted to completely penetrate their blanks with the carbon had more problems with tool breakage, if left in a hardened state. Many students commented that the cutters actually seemed to work better than the high-speed steel and carbide cutters that they previously used. This proved true as long as the cutter was kept cool either by using coolant or by lowering the cutting speed. If the cutter became too hot, it quickly softened and wore down rapidly at that point.

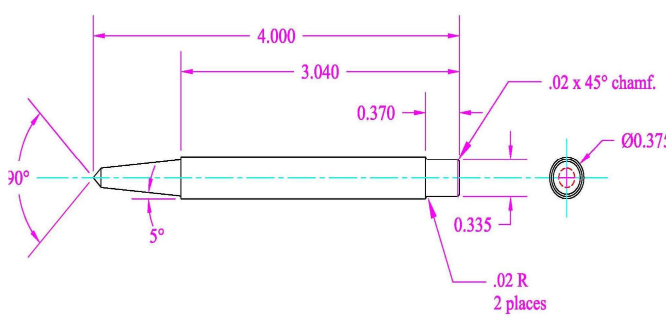

Figure 13. Center Punch Made in Stage 2

Figure 14. Technology Students Machining the Center Punch in Stage 2

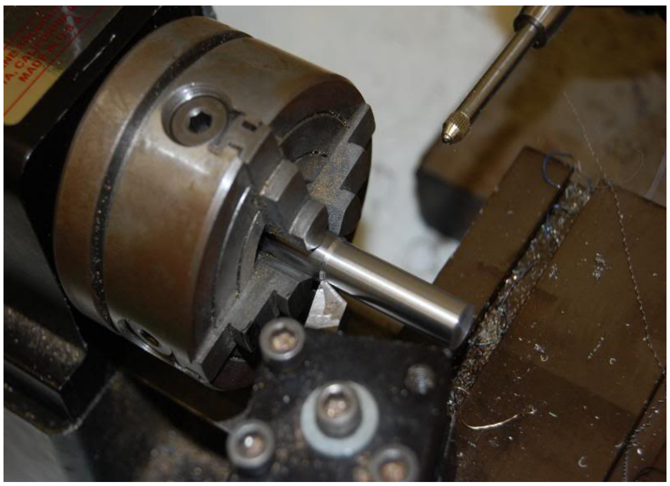

Figure 15. Machining the Center Punch in Stage 2

The center punch, shown in Figure 16, required a different approach than the lathe bit. Students found that simply carburizing the tip was not effective because the softer material behind the hardened tip would deform easily during use, resulting in a bulged appearance behind the tip. Another observation that students was made was that it really was only desirable to have the tip hardened; the remainder of the punch body could be left soft, which was desirable since the head was going to be struck with a hammer frequently. What was clear, however, is that all of the groups understood the need for more carbon at the tip; once this was realized, the groups used a differential hardening process where only the tip was quenched after reaching the critical temperature. Following the hardening operation, students found during research that the appropriate temperature for tempering a center punch was 475 °F in two separate one-hour cycles.

Figure 16. Center Punch Created in Stage 2

Stage 2 Summary

One often-heard concern among some in industry is that graduates from engineering and technology programs do not have enough practical, hands-on knowledge when they graduate. John Fuhs, vice president of sales for Swoboda, Inc., a subsidiary of a German auto parts provider, mentioned the difficulty his company had in finding engineers with the necessary hands-on skill set needed to make their factory run at peak efficiency. American graduates, they were finding, were far more knowledgeable about project management; but, when it came to the technical issues, Fuhs preferred interns and graduates from engineering programs in Germany that taught what Fuhs felt were essential elements such as tool making [10]. In this current study, students who completed the two stages walked away with a good general understanding of heat treatment as it applies to tool making. The simple processes that they learned about first-hand required not only research but also demonstrated critical-thinking skills, which seem to be the very traits that Mr. Fuhs felt were lacking in the employees that Swoboda employed. The basic principles learned in this activity can be applied to more complex problems in industry and can also serve to provide a better foundation for more complex metallurgical problems.

Stage 3

1. Using your activities as a reference, answer the following questions drawing parallels from your lab activities and the theoretical principles covered previously using appropriate metallurgical terminology. Be very detailed in this step using both written and visual descriptions and include the information from the following questions in your response.

a. Explain the importance of carbon in the making of steel in terms of the difference in solubility of carbon.
b. Explain the phase change between austenite and ferrite; between austenite and pearlite, both under equilibrium conditions.
c. Using a TTT diagram for conventional quenching, trace the transformation of austenite to martensite; describe martensite in terms of hardness, brittleness, ductility, and toughness.
d. Explain the reasons for tempering martensite and how the differences between tempered martensite and martensite are achieved.
e. Explain why fine grain metals are stronger and harder than coarse grained metals at or near room temperatures.
f. Explain the need for coarse grain materials for high temperature applications.
g. List three ways that you can refine the grains
h. Define surface decarburization in terms of atoms in the solid state. Give two possibilities for corrective action with a metal that has a decarburized surface which requires a wear-resistant surface.

Conclusion

The activity described here can be varied considerably based on the needs of the program and availability of equipment. Steel has been heat treated successfully hundreds of years before electric furnaces and accurate pyrometers existed and can still be done today with some basic equipment. For programs lacking a heat treatment oven, it may be desirable to modify projects to utilize simple oil hardening carbon steels like SAE 1080 or water hardening steel such as W1 in place of the mild steel used in the activity described above. Both 1080 and W1 are readily available and are inexpensive. In addition, both types of steel respond very well to simple heat treatment methods, something that more complex tool steels do not.

One problem that exists with many modern technologies is that oftentimes they make a task too easy and may in the process remove the requirement for critical thinking. It is easy to turn on a modern heat treatment oven and set the readout to a specified temperature found in a machinist's handbook, yet much is happening behind the scenes that a student will never see. For instance, when performing a heat treatment process without the use of sophisticated equipment such as temperature controlled furnaces, the operating temperature must be gauged using less technical, but still accurate, methods. One common approach is to take advantage of the fact that when steel nears the austenite phase, it suddenly loses its magnetic attraction. This can, of course, be verified by using a magnet to test the material as it is heated. Once the magnetic attraction has been lost, the steel can be observed under low-light conditions and brought up one shade of red higher, which will indicate that the critical temperature for that specific alloy has been reached. It is even possible to witness the phase change, or the restructuring of the molecules, of the material by observing the color change under low-light conditions. The part can then be quenched in either warm vegetable oil (canola) or water—depending on the specifications of the steel type.

After the hardening operation has been performed, the material can be polished and heated once again with the aid of a propane torch. As the material temperature rises, oxide layers will build up on the surface and the color of the material can be used to assess the desired temperature. This is a very simple method; and while it may not yield the precise results that modern heat treatment equipment can provide, it was a method that was successfully used for most of recorded history. This simplified format using traditional processes could perhaps provide valuable lessons about heat treatment for high school pre-engineering programs.

Other Possibilities

Just as this activity can be scaled down, it can also be readily scaled up. One possibility is to have students take the first stage further and attempt to make a spring from their test strips. Making a spring can be difficult, even with good quality steel of known chemistry. However, the steel created in this activity has numerous deficiencies ranging from uneven carbon content and distribution to coarse grain structure. This would be a great opportunity for students to conduct further research on material testing such as the Rockwell hardness shown in Figure 17, while also learning about methods of grain refinement, which was done in the original activity—a successful spring is shown being tested in Figure 18.

Programs with access to more sophisticated equipment might even wish to further expand on this project by using more advanced equipment such as the scanning electron microscope (SEM). This can be a remarkable way for students to examine the surface structure and chemistry of the material. Figure 19 shows the complex surface structure of a bone-and-charcoal-colored case-hardened sample produced by students and examined under the SEM.

The possibilities listed here are just a few variations that can be added to this activity. Resources of the program and the ingenuity of the instructors are the only limitations.

Figure 17. Student Verifying Rockwell Hardness after Heat Treatment

Figure 18. Testing a Completed Spring

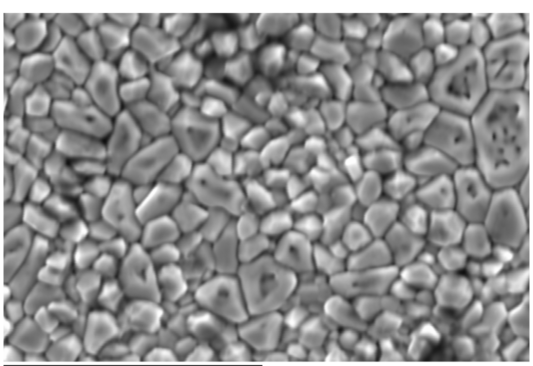

Figure 19. Image Taken with a Scanning Electron Microscope Showing the Surface Structure of a Bone-and-charcoal-colored Case-hardened Sample

References

[1] Felder, R. M. (2012). *Engineering education: A tale of two paradigms*. North Carolina State University.

[2] Matthews, M. (2014, January 28). *Retention project.* Retrieved January 28, 2014, from American Society for Engineering Education: http://www.asee.org/retention-project/keeping-students-in-engineering-a-research-guide-to-improving-retention

[3] Jonassen, D. H., Peck, K. L., & Wilson, B. G. (1999). *Learning with technology: A constructivist perspective.* Upper Saddle river, NJ: Merrill.

[4] Miller, J. W. (2012). *Global Steel Industry Faces Capacity Glut*. Wall Street Journal.

[5] Fulford, M., Sim, D., Doig, A., & Painter, J. (2005). In defence of Rome: a metallographic investigation of Roman ferrous armour from Northern Britain. *Journal of Archeological Science*, 241-250.

[6] Johnson, C. G., & Weeks, W. R. (1972). *Metallurgy*. Chicago: American Technical Society.

[7] Dossett, J. L., & Boyer, H. E. (2006). *Practical heat treating.* Materials Park, OH: ASM International.

[8] Briney, D. (1983). *The home machinists handbook*. McGraw Hill: New York.

[9] Goddard, W. (2000). *The wonder of knifemaking.* Iola, WI: Krause Publications.

[10] Brown, A. (2009). *What engineering shortage?* The Bent of Tau Beta Pi, 21-25.

Biographies

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RESULTS OF A SERVICE-LEARNING PROJECT THAT SPANNED TWO CLASSES

Tom McDonald, University of Southern Indiana

Abstract

Service learning occurs when students participate in a service activity that meets a community's need. Service learning also provides students with opportunities for learning in both the classroom and in the real world. Students are able to interact with a community partner or sponsor in order to effect change. In this paper, the author discusses a service-learning project completed by two separate classes, the results of the work by each class, and observations about the service-learning process when it involves more than a single class.

Introduction

Service learning occurs when students participate in a service activity that meets a community's need [1]. Service learning provides students with opportunities for learning in both the classroom and in the real world and potentially changing their attitudes towards a course or subject [2]. Students are able to interact with a community partner or sponsor in order to effect change [3]. Presented here is a service-learning project that was performed at a regional airport in southwest Indiana that serves a city of approximately 100,000, plus the surrounding 50 miles. The airport has ten gates and daily serves five national-hub airport locations in the United States [4]. The project was undertaken at the request of the airport as part of its 3–5 year strategic plan for improving customer service. The project was completed by six students across two classes taught in the Engineering Department at a university in southwest Indiana. One student was in both classes and served as the primary contact for sharing information between the classes.

A process map divides a manufacturing process into a series of indivisible elements. Each element is then described with a name, the type of equipment required, personnel, resources, and time required to complete the element [5]. Process mapping develops a model that shows the relationship between these elements for a specified output. Biazzo [6] stated that one reason for the widespread use of process mapping is that it has been recognized that such models offer useful, inexpensive descriptions that can help improve business processes.

Discrete-event simulation (DES) is the "modeling of systems in which the state variable changes only at a discrete set of points in time" [7]. DES has been used in manufacturing [8], logging [9], chemical processing [10], web-based applications [11], and in the airline industry [12]. Discrete-event simulation uses a computer program to model the system of interest. Such programs include Arena®, ProModel®, Excel, and Visio. These software programs, when combined with the process map, can be used to analyze and simulate the changes suggested for improvement [13].

Description of the Projects

The service-learning project involved two engineering classes, a process improvement class, and a discrete event simulation modeling class, performing separate projects where one project fed information into the other project. The overall goal of the project was to gain an understanding of the passenger flow, the amount of time it takes passengers to be processed through the airport, and to improve passenger experience. The first project was to determine the flow of passengers from the airport parking lot through boarding of the plane; and the reverse, from de-boarding the plane to leaving the parking lot. The second project was to develop a discrete event simulation model of the process flow of the passengers. The process maps developed by the process improvement class were used to help build the simulation model of the airport. The simulation model was then used to determine a rough estimate of the time it takes passengers to flow through the airport for both arriving and departing flights.

Process Improvement Project

The process improvement project focused on the flow and flow times of passengers arriving and departing from the airport, as well as baggage processing times. The second aspect of this process improvement project was to determine how to improve the passenger experience while in the airport. This was a concern of the airport, especially in cases where there were delays due to weather or unforeseen issues that were going to delay the passengers from reaching their destinations. While collecting data for the process layouts and simulation model, students looked for areas of improvement that would increase customer satisfaction.

Airport officials had no empirical data on the time required for passengers to move through the airport. Accurate information of this type is needed to determine the impact on passengers if there are issues at check-in, security, or plane boarding. A primary concern of the airport was the time required to process the baggage for both departing and arriving flights. Students made multiple visits to the airport to collect data for these processes.

Four process maps were developed corresponding to the following:

1. Passengers arriving for a flight (departure)
2. Baggage of flights leaving the airport
3. Passengers arriving via airplane (arrivals)
4. Baggage of flights arriving at the airport

The processes for each of the process maps developed are shown in Table 1.

Table 1. Processes in Each Process Map

Process Map	Processes
Departing passengers	1. Parking or drop off 2. Entering airport 3. Flight check-in, including baggage 4. Processed by security
Departing baggage	1. Check baggage 2. Baggage security scan 3. Load on baggage cart 4. Load on airplane
Arriving passengers	1. De-boarding the plane 2. Claiming baggage 3. Renting car or leaving via personal vehicle
Arriving baggage	1. Unload carry-on baggage 2. Place carry-on baggage for pick up 3. Unload checked baggage 4. Transport to terminal 5. Offload at appropriate terminal

Discrete Event Simulation Project

The simulation model focused on the flow times of passengers arriving at and departing from the airport. The process maps from the process improvement project were used to help determine the processes for the simulation model. The departure times were collected for the entire process that passengers went through from the time they entered the parking lot until they boarded the airplane. Passenger arrivals by car were categorized into two categories: 1) taxi/drop-off and 2) short-/long-term parking.

Data were collected for both categories in order to determine the arrival times and processing times for the rental car area. To determine the interarrival times of customers departing from the airport, the total number of passengers arriving at the airport was divided by the observation time. The processing times for the kiosks, check-in stations, security, and baggage processes were determined by entering the data into Arena's ® Input Analyzer. The Input Analyzer determines the best-fit statistical distribution. Data for the times for each of the processes were entered into Arena® to provide a model of passenger flow through the airport.

Parking Lot to Airplane

The check-in times were documented for the two airlines serving the airport. The check-in times were recorded for times at the Kiosk and noted if the passengers had baggage or just carry on. The check-in times were documented the same way for passengers that went directly to the check-in counter with or without baggage. Times were also included for the average amount of time that it would take for a person to walk from the door to each of these areas.

The security times that were recorded included the ID check time and screening time. The ID check time was relatively quick. The screening times included the time it took passengers to walk through the entire screening process until they were finished getting the carry-on baggage screened. The carry-on baggage times were documented from the time the items were placed onto the conveyor belt until the passengers were able to collect their baggage. Boarding time was determined by dividing the total time it took all passengers to board by the number of passengers boarding the plane.

Airplane to Exiting the Airport

The airplane arrived at the gate and then the passengers either waited for their carry-on luggage or proceeded to baggage claim. Wait time for both carry-on delivery and baggage claim was a concern for airport management because they did not have an estimate of how long that took. After retrieving their luggage, passengers then proceeded to either the pick-up area or to their cars to exit the airport.

Process Improvement Project Results

The four process maps are shown in Figures 1–4. Figure 1 details the arrival of passengers to the airport from the parking lot along with their processing through check-in, security, and boarding the plane. The process map for how baggage for departing passengers is checked for hazards is shown in Figure 2. Figure 3 details the processes for passengers arriving by plane including the collecting of baggage, as shown in Figure 4.

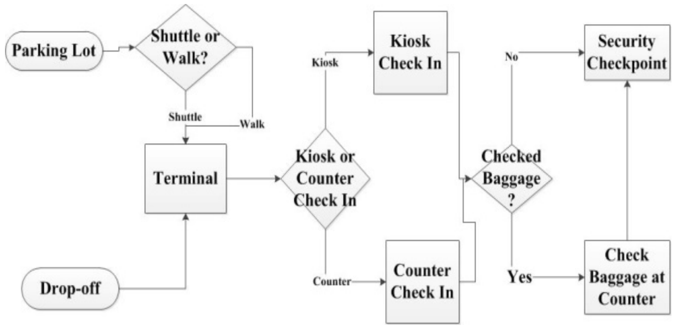

Figure 1. Process Map for Departing Passengers

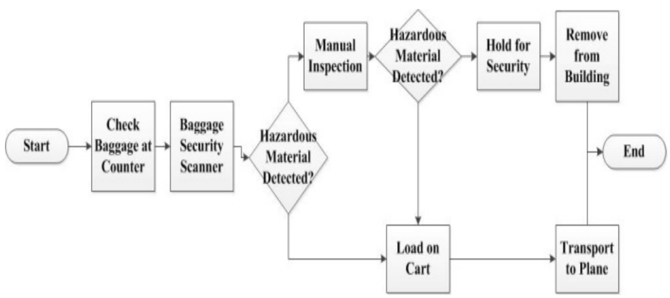

Figure 2. Process Map for Checked Baggage

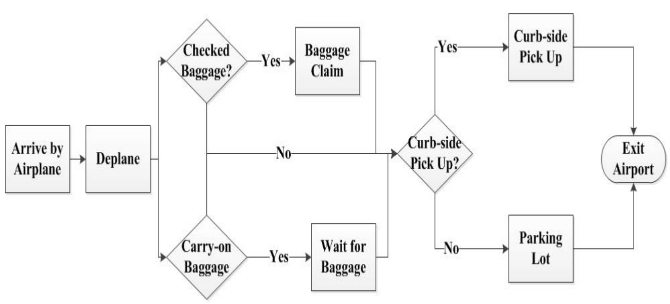

Figure 3. Process Map for Arriving Passengers

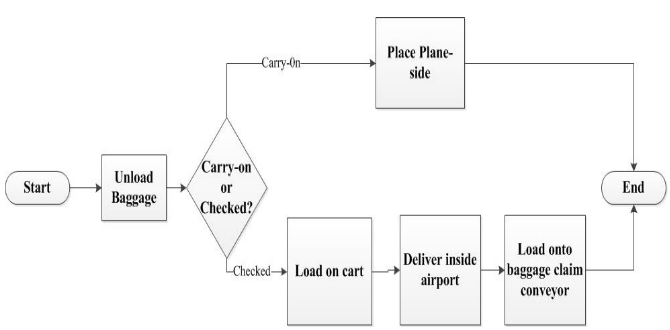

Figure 4. Process Map for Arriving Baggage

The data collected during the development of Figure 1 showed that 86% of the passengers park in either short-term or long-term parking, and 14% are dropped off at the terminal. Upon entering the airport, 50% check in using the stand-alone kiosks, and 50% go to the counter to check in. Eighty-seven percent of the passengers checked their baggage. Passengers then proceeded to the security check. Figure 1 shows that passengers would proceed directly from check-in to security. This may not always be the case, but airport management was interested in how long it took passengers to proceed directly from check-in to security, and this was the time used for both the process improvement project and the simulation project. At the security checkpoint, passengers went through three processes: ID/boarding pass check, baggage scanning, and passenger scanning. The ID/boarding pass check had to be completed prior to entering the queue for the baggage and the passenger scanning processes. Baggage scanning and passenger scanning operated in parallel with each other. After passing through the security check point, passengers waited in the boarding area until time to board the airplane.

While passengers were being processed through the security checkpoint, any checked baggage was also being processed so it could be loaded onto the airplane. Figure 2 shows the processes required to get checked baggage from the airport into the airplane. After checked baggage is collected at check in, it is delivered to the checked baggage security scanner. If no hazardous materials are detected, the baggage is loaded onto a cart to be delivered to the airplane. If a hazardous material is detected, a manual inspection of the baggage is conducted. If the manual inspection finds no hazardous materials, the baggage is loaded onto a cart to be delivered to the airplane. If a hazardous material is detected, the baggage is held for security to be collected and removed from the airport.

Figure 3 details the processes passengers arriving by plane before leaving the airport. Passengers arrive by plane and then exit the plane. Passengers are then categorized into three categories:

1. Passengers with checked baggage
2. Passengers with carry-on baggage
3. Passengers with no baggage

Passengers with checked baggage proceed to baggage claim to wait for delivery of their baggage before proceeding to the parking lot and exiting the airport. Passengers with carry-on baggage wait planeside to collect their baggage and then proceed to the parking lot and exiting the airport. Passengers with no baggage proceed directly to the parking lot and exit the airport.

Figure 4 shows the process map for baggage arriving by airplane. Baggage must be offloaded from the airplane. If baggage is carry-on, it is sent planeside for collection. If the baggage is checked, it is loaded onto a cart and proceeds into the airport to be loaded onto the appropriate conveyor to be carried to passengers in baggage claim.

The last aspect of the project was to develop ideas that could improve the passengers' experience while in the airport. The following recommendations were made based on an analysis of the current layout of the airport:

1. Move the check-in terminals for both airlines adjacent to each other to reduce distance traveled by passengers and streamline flow. It also opens up space for a potential remodel.
2. Flight arrival and departure monitors need to be moved to high-traffic, visible locations. Increase the number of monitors and size of the text on the screens.
3. Place a pass-through window between the bar and restaurant with personnel vetted by security on each side of the window to serve food to passengers who have passed security.
4. Place a fountain in the middle of the lobby to provide a focal point to passengers.
5. Update carpet and lighting as well as décor.

In the current layout, once passengers have passed through security, there is no place to get food. By implementing item 3, food could, at a minimum, be ordered and received at a take-out window. It was felt that implementing these suggestions would improve the flow and increase customer satisfaction with their experience.

Discrete Event Simulation Results

The model was run for 25 replications of 18 hours each and statistics were collected for the average time through the entire process as well as average processing and queue times for each of the workstations. The results of the simulation model for departing passengers showed that the time to process passengers from arrival to boarding was, on average 6.8 minutes, with a maximum time of 24 minutes. The longest process was at check-in, accounting for upwards of 17 minutes of wait time. All other average wait times were less than one minute. Passengers arriving by plane without checked baggage were able to exit the plane, walk to either the drop-off area or parking area, and exit the airport on average in 5.5 minutes. Passengers with checked baggage exited the airplane, walked to baggage claim, collected their checked baggage, made their way to their means of exiting the airport, and exited the airport on average in 15.6 minutes.

Project Conclusions

This project involved collecting several forms of data from a regional airport in southwest Indiana. From these data, process maps and two discrete event simulation models of the airport were created. The airport officials cannot address the longer processing times at check-in because the airlines control the number of employees at check-in. Anecdotal evidence indicated that processing through security was an issue. However, the simulation model did not indicate that was the case. This may be due to the fact that the security lines did not have any failures when the students were collecting data.

Overall Observations

As with many projects, communication is vital. The author found that communication between the students, both within groups and across the groups, was lacking. With a single student in both classes, data sharing was minimal without the direct intervention of the author. The author found that by combining the project across two classes, more supervision and forced communication were required than if the two projects were treated as separate projects. Lack of teamwork training may have also played a role in the lack of communication. While the students were all juniors or seniors who had been on teams before, none of them had ever had any training on the roles within a team and how to work together as a team.

Additionally, the students had a difficult time scoping their portion of the project and maintaining the scope that they did develop. Lastly, this was also the author's first attempt at incorporating service learning into a class. In the end, the airport was pleased with the results and the work completed by the students. However, with better communication and data collection, the students may have been able to include other aspects of the airport, such as the rental car area, that were not included in this project.

Acknowledgements

This work was sponsored by the University of Southern Indiana's Center for Applied Research and Economic Development.

References

[1] Flinders, B. A. (2013). Service-learning Pedagogy: Benefits of a Learning Community Approach. *Journal of College Teaching & Learning, 10*(3), 159-166.

[2] Butler, M. (2013). Learning from Service Learning. *PRIMUS, 23*(10), 881-892.
[3] Levesque-Bristol, C., Knapp, T. D., & Fisher, B. J. (2010). The Effectiveness of Service-learning: It's Not What You Always Think. *Journal of Experiential Education, 33*(3), 208-224.
[4] Airport, E. R. (n.d.). *EVV Facts*. Retrieved April 4, 2013, from http://evvairport.com/About_EVV/evvfacts.htm
[5] Linton, J. (2007). Process Mapping and Design. *Circuits Assembly, 18*(2), 26.
[6] Biazzo, S. (2002). Process Mapping Techniques and Organisational Analysis: Lessons Learned from Sociotechnical Systems Theory. *Business Process Management Journal, 8*(1), 42-52.
[7] Banks, J., Carson III, J. S., Nelson, B. L., & Nicol, D. M. (2000). *Discrete-Event Simulation* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.
[8] McDonald, T. N., Van Aken, E. M., & Rentes, A. F. (2002). Utilising Simulation to Enhance Value Stream Mapping: A Manufacturing Case Application. *International Journal of Logistics: Research and Applications, 5*(2), 213-232.
[9] Beaudoin, D., LeBel, L., & Soussi, M. A. (2012). Discrete Event Simulation to Improve Log Yard Operations. *Information Systems and Operational Research*, *50*(4), 175-185.
[10] Sharda, B., & Bury, S. (2012). Evaluating Production Improvement Opportunities in a Chemical Plant: A Case Study Using Discrete Event Simulation. *Journal of Simulation, 6*(2), 81-91.
[11] Alam, F. M., Mohan, S., Fowler, J. W., & Gopalakrishan, M. (2012). A Discrete Event Simulation Tool for Performance Management of Web-based Application Systems. *Journal of Simulation, 6*(1), 21-32.
[12] Beck, A. (2011). Case Study: Modelling Passenger Flows in Heathrow Terminal 5. *Journal of Simulation 5*(2), 69-76.
[13] Kumar, S., & Phrommathed, P. (2006). Improving a Manufacturing Process by Mapping and Simulation of Critical Operations. *Journal of Manufacturing Technology Management, 17*(1/2), 104-132.

Biographies

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