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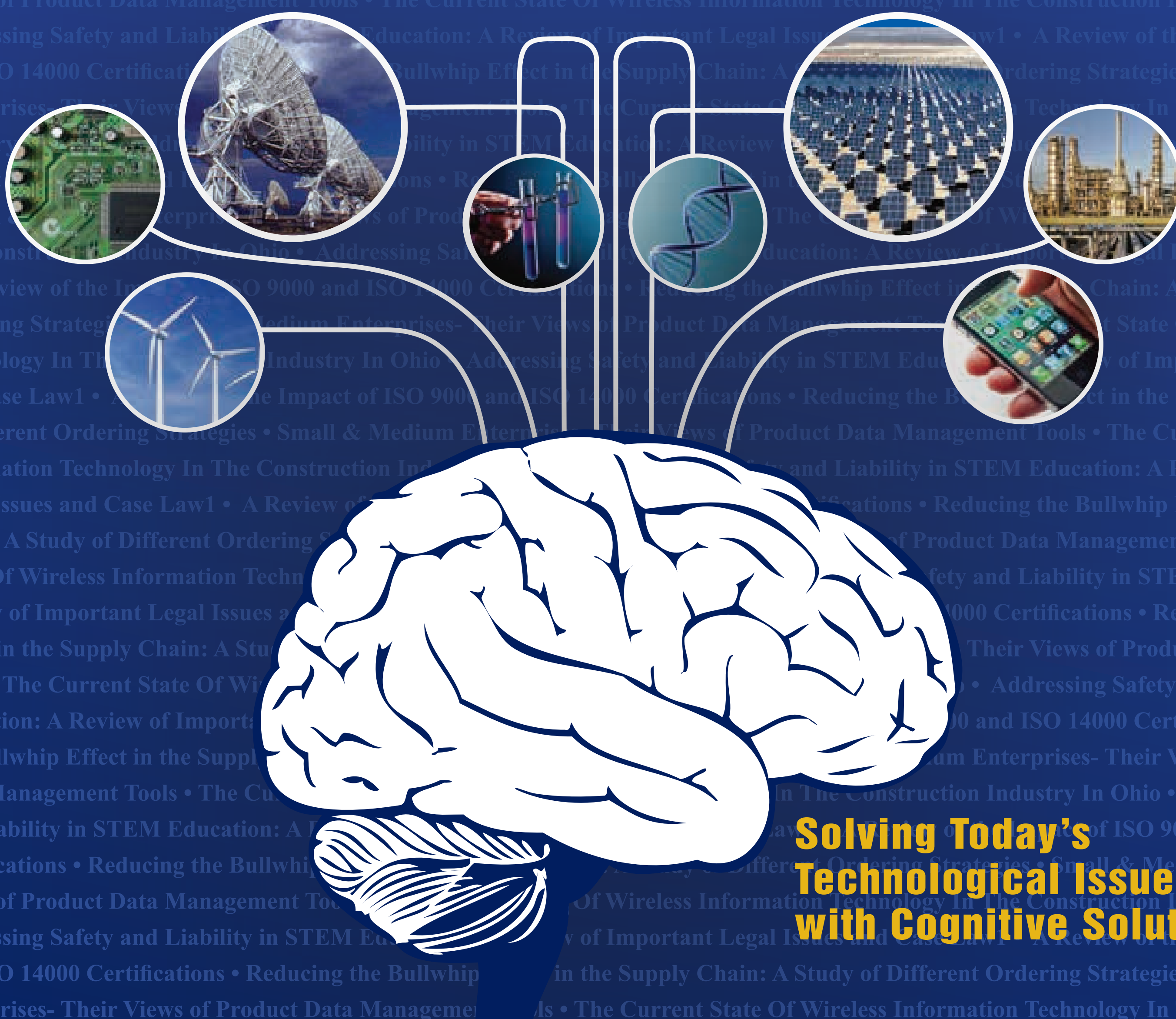

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Jerry Streichler, Founding Editor and Publisher from 1977-2006

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Volume XXXIX, Number 1, Spring 2013

Small & Medium Enterprises-
Their Views of Product Data Management Tools

By Karen Waldenmeyer and Nathan Hartman

ABSTRACT

This study was conducted as a means to discover common traits associated with small and medium manufacturers, especially ones who have adopted product data management (PDM) systems as a method to control engineering design and manufacturing data. After qualitative interviews were conducted with leading experts across industry sectors, a survey was developed and sent to small and medium manufacturers in the United States. The study concludes a number of interesting findings about the state of PDM usage within various segments of the industry, including general uses for engineering design systems, level of data exchange with customers and suppliers, and satisfaction levels with information querying, concurrent engineering contributions, and imposed restrictions. The study concludes that there are a few major factors that determine a company's success with using design and data management systems, including frequency of data exchange, data reuse, digital data formats used, and employee counts and locations.

Keywords: Product data management (PDM); product lifecycle management (PLM); data exchange; small and medium enterprises; computer-aided design (CAD)

INTRODUCTION

Small engineering firms usually operate in challenging environments – many are subject to the whims of their customers, who are typically larger, more well-known manufacturers (Towers & Burnes, 2008). This changes the normal design process model, where the company must "talk to customers" and make sure they are producing a product "that customers want." Instead, these small and medium enterprises (SMEs) are usually given very specific details to which their product must conform in order to meet their customer's specifications (Arendt, 2006). Sometimes this requires SMEs to be very flexible in their choice of product lifecycle management (PLM) tools, based on how many different customers they are serving.

Products are increasingly being designed with three-dimensional (3D) tools that enable a host of different analyses, simulations, and design changes. Unfortunately, the software that enables this new design methodology is not nearly as accessible to SMEs as it is to larger, more robust manufacturers. Although their customers most likely have created the requisite network infrastructure for their 3D product data due to the sheer volume and breadth of the data, many SMEs have not yet adopted any formal strategy for managing their product data for their own smaller, yet complex, design methods (Hicks, Culley, & McMahon, 2006). This main impetus of this study was to examine the inexperience of SMEs in the use of 3D product design and data management tools, to understand the challenge SMEs face with regard to data management due to their inexperience, to identify their common product data management needs, and to better align technology with their core business goals.

The main research focus of this study was in product data management (PDM), which is a technology that seeks to manage, secure, control, and accelerate the product development process by ensuring that all product data, particularly product definition data, is stored in one secure, easily accessible and manageable location. Many PDM systems can be difficult and costly to install and implement, particularly in SMEs that have limited resources and potentially higher vulnerability to implementation failures (Chen, Huang, Yang, Lin, & Chen, 2007). Along with the use of these systems come many organizational changes to which SMEs may be unaccustomed, such as increased collaboration between areas of the business and entities outside the business. However, their smaller size tends to allow the SMEs to be somewhat flexible in their technology implementations.

SMEs are typically classified as employing less than 500 people each, and they employed approximately 6.1 million U.S. citizens in

2006 in the manufacturing industry alone (Statistics about Business Size from the Census Bureau, n.d.). At the same time, SMEs have to compete for resources and market share in a manufacturing industry that is struggling to stay afloat since the unstable economic environment of 2008 to present. Manufacturing SMEs are in a particularly unique situation because of limited resources, increased level of flexibility, high amount of personal relationships within the company, and relatively low levels of bureaucracy, among other things (Marri, Gunasekaran, & Grieve, 1998). These companies have been relatively slow to adopt new design technologies like 3D CAD, product lifecycle management philosophies, and product data management technology (Walters, 2007). Many manufacturing and design SMEs still have not updated their systems and processes for reasons such as cost, having simpler product lines, or simply not needing to because of the specific product or product lines that they manufacture and sell (Ayyagari, Beck, & Demirguc-Kunt, 2007). However, many SMEs have moved toward new methods of product design by doing the bulk of the design work with 3D CAD tools, and it is important to pinpoint the exact reasons why these organizations are updating and what levels of success they have had (Dibrell, Davis, & Craig, 2008).

Through PLM an organization in the manufacturing sector is encouraged to consider work in terms of a product, instead of a process (Ameri & Dutta, 2005). This usually means a reorganization to distance itself from a "departmental" environment where each department is like an isolated island and communication is deemed "over the wall" to a newer, more flexible design process that focuses on a single product or family of them, with specialists from different backgrounds collaborating together from the beginning of the product's design phase all the way through its disposal (Sääksvuori, & Immonen, 2005). Thus, it is useful to get a better picture of what drove manufacturing SMEs to make such drastic changes to their business processes, adopt new PDM technology to manage all the newly generated data, and how this worked out. This research can be a good resource for small companies who are considering the same processes to remain competitive in their industry.

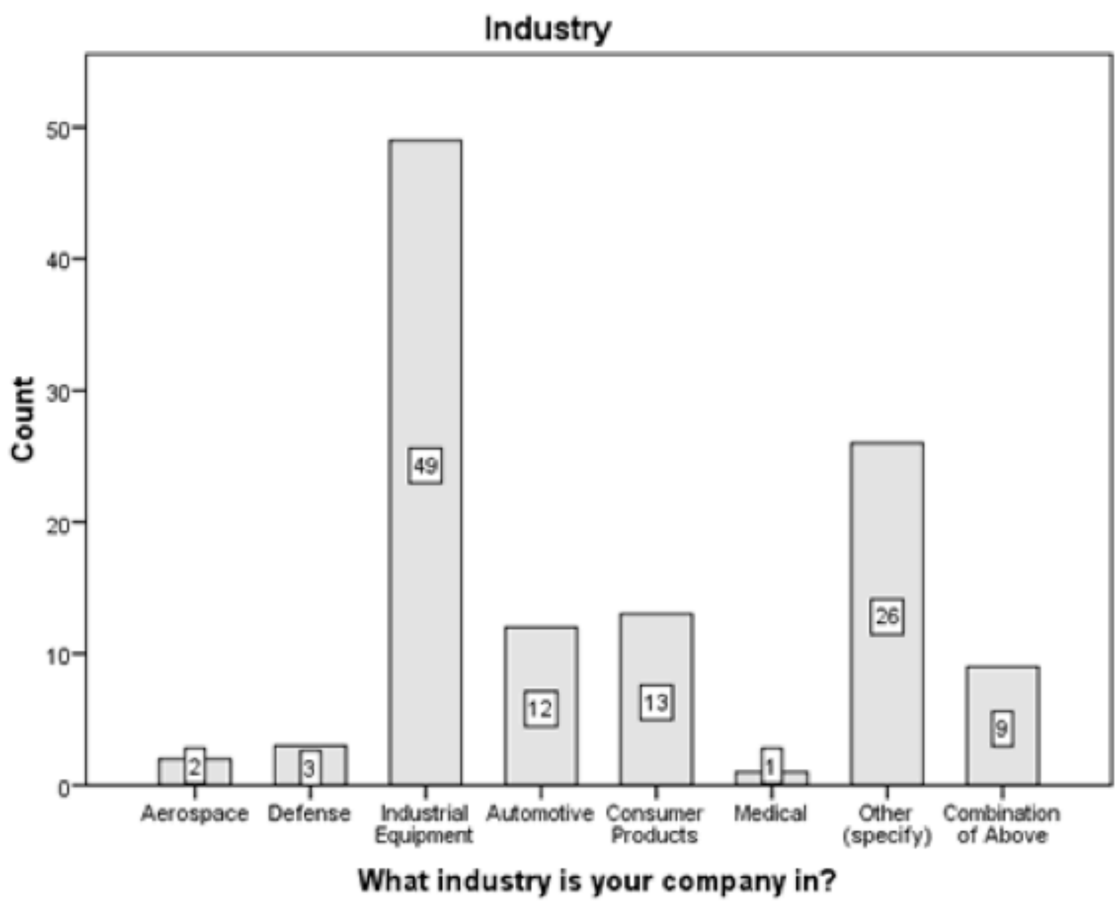
RESEARCH METHODOLOGY

In an effort to investigate the transition of SMEs toward integrated product lifecycle technologies and systems, two simple research questions were developed. What are the common traits of small and medium manufacturing businesses that have adopted a digital product data management (PDM) system? Furthermore, how has this PDM technology affected them? This study used mixed-method data collection schemes because of the complex nature of the research questions and the number of variables. Because the subjects are companies, which even on a small scale can be incredibly complex, a combination of preliminary interview feedback and broader survey methods proved to be the most useful strategy to employ. The study consisted of four preliminary interviews with targeted PDM experts that covered broader PDM issues relative to communication with suppliers and customers; it also considered how PDM technology has affected those processes. From these interviews, a survey was developed, which was validated by a PDM expert in the aerospace industry because of the industry's exposure to supply chain variation and small and medium enterprises. The survey included five-point Likert scale and multiple choice questions, as well as free-response questions (Dillman, 2007). The responses to these questions tended to illustrate the aspects of PDM implementation that SMEs benefit from, as well as the elements that they tended to have more difficulty getting through. From these responses, conclusions were made about the experiences SMEs have had relative to implementing and using PDM.

Because of the relative lack of previous literature examining manufacturing SMEs in the United States, a short interview was held with four different experts in PDM implementation and management in companies where this has become prevalent (Myers & Newman, 2007). Although not all of the subject matter experts were employed by small or medium companies (in terms of the definition for this study) they were asked what their relationships were with their suppliers, who tended to be small or medium companies, and how they dealt with the differences in PDM capability. After the interview recordings were fully transcribed, qualitative discourse analysis methods were used to extract the main idea threads from the dialogue (Strauss & Corbin, 1998). The basic strategy for coding the transcribed interviews was to summarize general ideas, organize and rank these concepts based on frequency, and then create basic concepts for which quantitative survey questions would be based (Glaser & Strauss, 1967). This required approximately three to four passes through the transcript to both generate codes and group them appropriately. Major themes that emerged from these interview transcripts were issues around data retrieval, exchange, and formatting; PDM as a technology; and the information technology resources necessary for PDM care and maintenance; user interaction barriers; and levels of financial investment required to support the PDM environment. These main ideas were used to create survey questions that would best identify the important traits for SMEs that were either contemplating or currently using engineering design systems technology. For the purposes of this study, the label "engineering design system" was used in the survey to describe a digital system that is used to track, control, and secure product definition data. This choice was made for several reasons: (a) the term "PDM" is not common within the SME space, (b) to reduce confusion between the terms "PDM" and "PLM" and their use in the SME space, and (c) to prevent respondents from discounting their system if it happened to be informal or internally developed.

Survey questions were developed based on these themes. The initial subset of survey questions were meant to form a framework for the characteristics of a small manufacturer. Questions such as number of employees, industry, and level of digital design were meant to give background for each company and give statistics on the true characteristics of the sample responding to the survey. Questions also included whether or not a company had a system set up specifically for handling engineering design data. If a respondent reported that the company did not, that person was automatically taken to the end of the survey and thanked for their time. If the respondent answered that the

Figure 1. Industry Sectors Represented in This Study

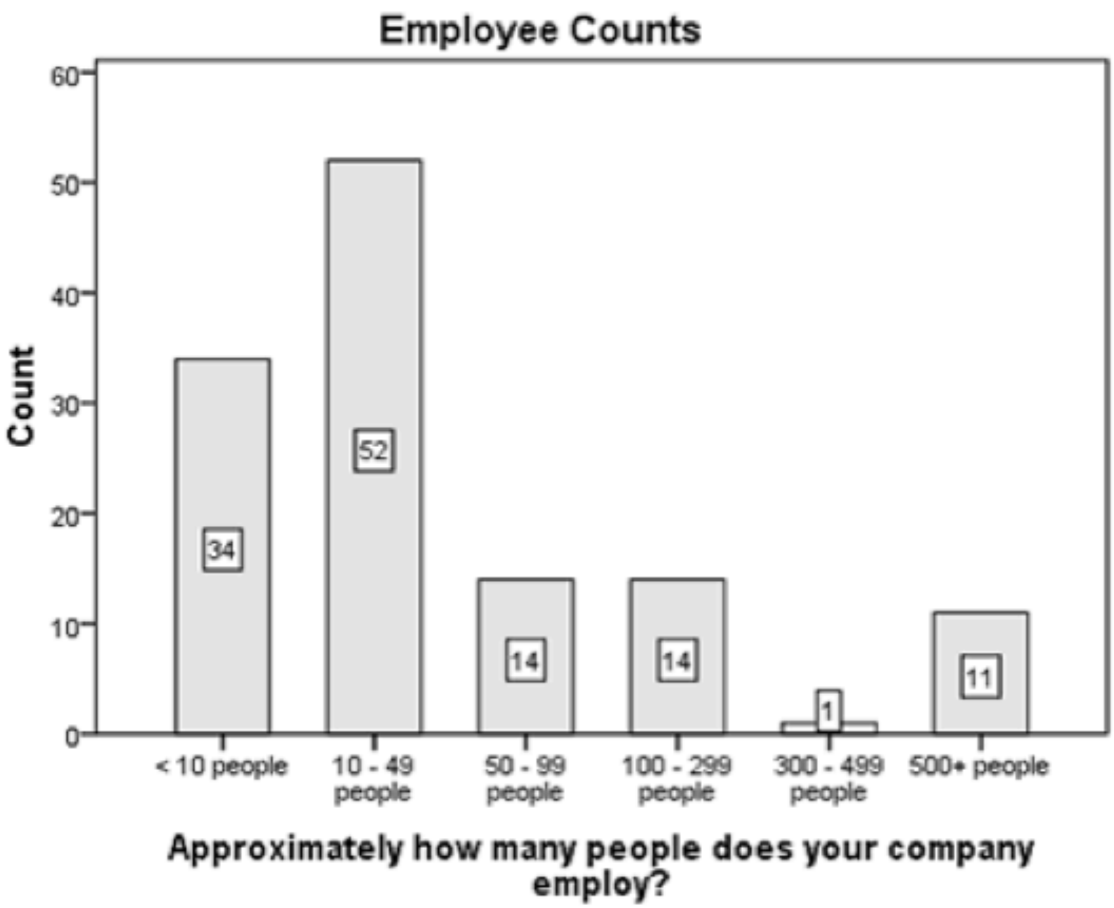


company did have an engineering data system of some sort, that person continued with the survey. Questions were also added to give a more accurate portrayal of the expertise of the survey taker by asking what their level of involvement was with the data management system. Other questions were based on the broader themes that were drawn from the qualitative interviews, such as methodologies for using the PDM system, workflow usage, opinions on how the PDM has affected the design process, and investment characteristics. Another major theme that generated a few different questions was the level of system integration between both the small manufacturers and their customers/suppliers, as well as within their own organizations.

DESCRIPTIONS OF SURVEY RESPONSES

Due to the nature of the data, the analysis includes discrete measures (averages and percentages of scores and frequency analyses). The large part of the analysis of quantitative data is the search for variable relationships and comparing and contrasting data between companies. This was accomplished using Pearson chi-square tests by comparing response levels between two independent variables, such as company size and PDM use. The overall goal of this research was to confirm similar studies to a degree while at the same time exploring critical factors about PDM implementation that have not yet been explored, specifically in the United States. Therefore, a survey was the most expeditious method to gain useful information from small manufacturers. The initial contact email was sent out to 2,200 potential participants across the United States. The majority of survey responses came during the first two days that the survey was opened. Within two weeks, 100 completed responses and 40 partial responses were received. The initial part of the survey asked general questions about the respondents' company's characteristics. Figure 1 explains the industry sector distribution for this study, and Figure 2 details the size of the companies that responded to the survey.

Figure 2. Size of Companies Responding to the Survey



Respondents who reported more than 500 employees in their businesses were removed from the sample. Of the completed responses, 42 respondents stated that the company used an engineering design (PDM) system. Despite the relatively low number of respondents for this portion of the survey, a number of interesting relationships were found that will be explored.

It is important to first discuss the business demographics from the survey sample because this provides a context for the results. These were not multinational companies with substantial IT resources. These were companies that often have people performing more than one organizational role without dedicated IT support. It quickly became clear that the majority of the small manufacturers classified themselves as being in the industrial equipment industry. They were about evenly split between having an engineering design (PDM) system and not having one, but the vast majority of them had fewer than 50 employees, versus some of the other industries such as companies in the automotive and other categories, which were more evenly dispersed in terms of employee counts. This is reflective of the manufacturing industry in the United States in general; whereas larger corporations make up the majority of the industry by sheer employee counts, there are far more individual smaller companies than large ones, and thus it makes sense that more small companies responded to the survey.

The final question targeted at the entire sample of survey respondents also caused the sample to be split into two specific groups: companies that have a digital design system of some sort, and those that do not. Respondents answering this question with a "no" were taken to the end of the survey and thanked for their time, since the subsequent questions would be about a system they did not have. Table 1 represents the relationship between presence of an engineering design system and basic company characteristics. The chi-square values indicate that there were no significant relationships between company characteristics and whether the company used an engineering design system.

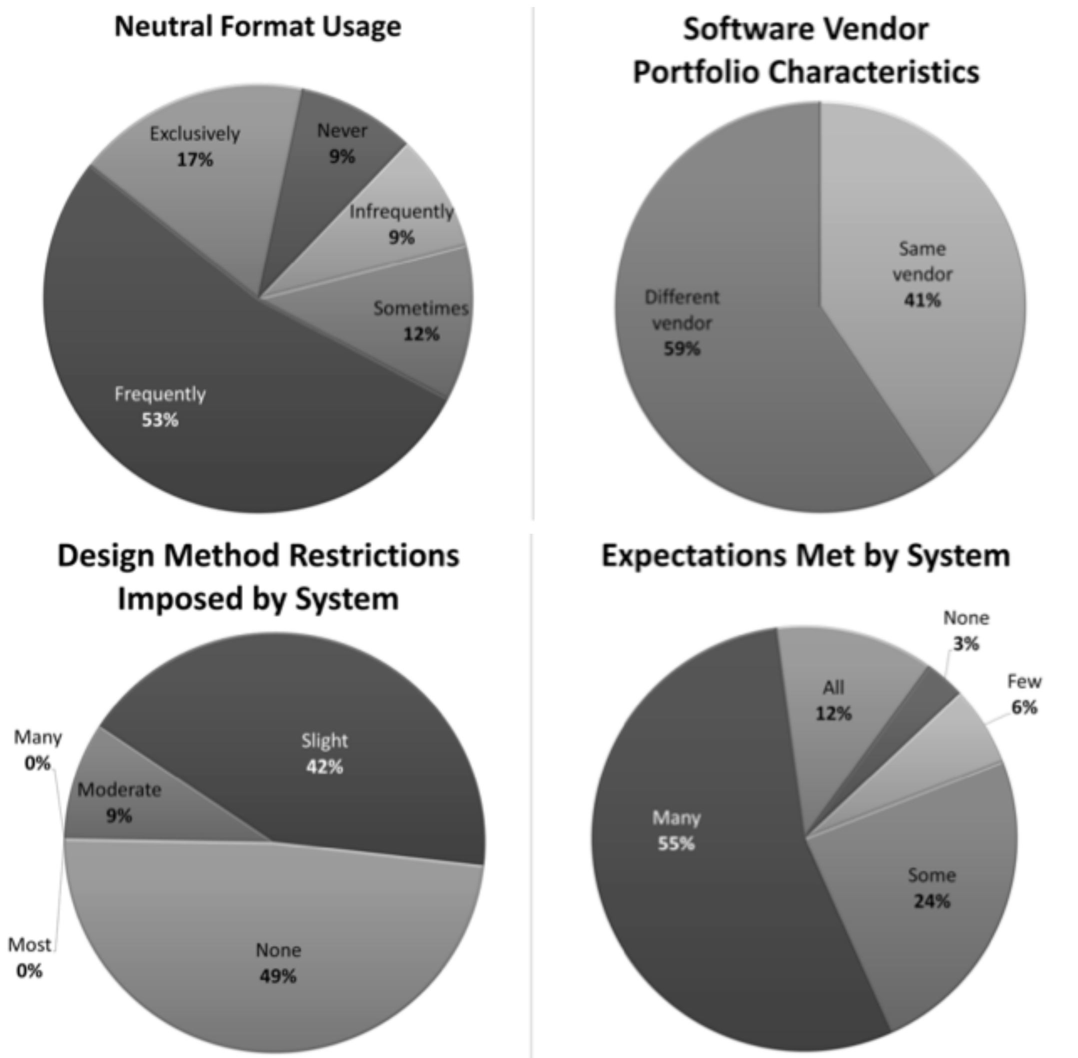
COMPARISONS OF COMPANIES WITH ENGINEERING DESIGN SYSTEMS

Several general findings were discovered from the data, as described in Figure 3. According to the survey respondents, they used neutral file formats frequently and tended to get their software from different vendors. Their design systems did not pose any major restrictions on their engineering processes, and their systems generally met their expectations. In many instances, the use of neutral files in data exchange and the use of multiple software tools (and the accompanying discontinuity of data usage) had a direct effect on the success of collaborative activities using digital product data.

Table 1. Comparison of Company Demographics to Presence of Design System

Variable 1	Variable 2	Chi-square
Industry	Presence of an engineering design system	.583
# of Employees		.098
# of Locations		.44
Digital format used		.071
OEM/Supplier/Both		.722

Figure 3. General Response Characteristics of Small and Medium Manufacturers



Though important conclusions can be reached based on basic metrics, there are also relationships between different variables, such as level of involvement in the system when compared with the perceived effect on the time it takes to find information to perform a task. Other relationships include the frequency of exchanging data with outside entities versus how the system has contributed to concurrent engineering, and the use of neutral file formats versus the organizational group that manages the design system. Table 2 represents the characteristics of companies that responded to the survey as having an engineering design system. It is a subset of the companies represented in Table 1. Based on the amount of responses returned and the number of variables examined, Table 2 includes those variables that formed a statistically significant relationship based on their chi-square values.

An interesting relationship was found between involvement level and attitudes toward how the system enables the finding of information. As seen in Table 2, It appears that users who rated themselves as "very involved" tend to feel that the system makes finding information slightly faster, whereas those who rated themselves as "extremely involved" feel the system makes finding information much faster.

Table 2. Characteristics of Those Companies with Design Systems

Variable 1	Variable 2	Chi-square
Digital Design Format	Industry	.060
Engineering Design Locations	# of Employees	.000
OEM, Supplier, or both	# of Employees	.118
OEM, Supplier, or both	Digital design format	.200
System maintenance group	Neutral file format usage	.013
System meets expectations	Involvement Level	.156
System meets expectations	Restrictions on design methods	.090
System meets expectations	Contribution to concurrent engineering	.004
System meets expectations	Data exchange frequency	.046
Contribution to concurrent engineering	Data exchange frequency	.052
Restrictions on design methods	Data exchange frequency	.000
Effect on informational retrieval time	Effect on design task time	.018
Effect on information retrieval time	Involvement Level	.025
Effect on information retrieval time	Data sharing beyond Engineering	.027
Workflow usage	Data sharing beyond Engineering	.136
Workflow usage	Data entry point during design	.065
System upgrades	Data entry point during design	.115

Another interesting correlation ($\chi^2 = .027$) that proved to be significant was the connection between whether an engineering design system shares data beyond just engineering, and how much effect the system has on finding information for a task. Respondents whose design system shares data tend to strongly feel the system makes finding information for their tasks faster, either slightly or much faster. This may due to the fact that the design tasks in an integrated design system must pull information from more sources, and thus a centralized location for data made finding information easier.

It also appears that respondents whose companies frequently exchange data with their customers and suppliers – more than a few times each week – tend to feel that their engineering design systems do not place many restrictions on their engineering design process ($\chi^2 = .000$). This could be because the data exchange capabilities of their design system save them time in other ways that affect how respondents feel about the restrictions the system puts on them, or there could be other reasons for this correlation.

Another correlation between variables was the one between the level of concurrent engineering these design systems tend to create, and how the systems met expectations ($\chi^2 = .004$). It appears that as systems tend to contribute more to concurrent engineering, respondents felt the systems met more and more of their expectations. That's partially to be expected considering that product lifecycle management as a concept is based on the idea of concurrent engineering and product focus rather than process focus.

DISCUSSION

Several compelling findings were gleaned from the data, such as that the primary usage of engineering design systems is the storage of manufacturing information for these small businesses, and they use neutral file formats frequently. They also tend to get their software from different vendors, but believe that their design systems do not pose any major restrictions on their engineering processes and their systems generally meet their expectations. There also seems to be interactions between different variables, such as level of involvement in the system when compared with the perceived effect on the time it takes to find information to perform a task. Others include the frequency of exchanging data with outside entities versus how the system has contributed to concurrent engineering, and the usage of neutral file formats versus the organizational group that manages the design system.

Two variables in particular stood out as having some effect on whether or not a company adopted a digital engineering design system: number of employees ($\chi^2 = .098$), and the type of digital formats used to define design ($\chi^2 = .071$). It makes sense that both of these variables are connected to the presence of a design system because typically a company that has adopted digital formats as a method to define design needs places to store, manage, and archive all this data over time. Software vendors that sell 2D and 3D design tools also often have file management tools of some sort that they may offer to companies for a lower price when bundled with the design tool itself. Also, companies that use 3D tools were more likely to have a system versus companies than used 2D tools. This is an interesting distinction, which can best be explained by the fact that 3D software vendors more often have a system that can be bundled with the 3D tool itself that was designed to be integrated together. The 2D tools may lack associative part management, which, for a company that does not necessarily need to maintain referential integrity between part files, could make a separate digital system for storing and managing 2D part files seem like a waste of resources.

Over 75% of respondents to the second part of the survey about engineering design systems reported that they were very or extremely involved in the system at their company. This is a generally good marker that the rest of the answers were relatively reliable, because it means that respondents were most likely generally knowledgeable about the systems used at their companies and their answers would be credible. Respondents also report that they used their systems primarily to store manufacturing information, and then as a general repository for data and product structure management and bills of materials. This indication, that the main use of engineering design systems is to store manufacturing information, is an interesting result given that the traditional PDM tool is built mostly for engineering design itself and typically must be modified or added to better support manufacturing information. It also shows that these small manufacturers are not in the “PLM” mindset, in that they were focused more on their processes than the product itself, which may be a good thing for them at the present time, but in the long term it may not be conducive with growth, given the advance of technology and competition.

The speed of tasks, particularly doing a design task and finding information, is usually the major benefit cited by companies who have adopted a robust PDM system (Philpotts, 1996). This benefit is also reflected in this study’s sample of small manufacturers, where the majority of respondents reported that their system makes design tasks faster or has no effect, and finding information in particular is either slightly or much faster.

Because these small manufacturers have relationships with multiple suppliers and customers, they happen to exchange data with these outside entities on a relatively frequent basis: most companies exchange data at least a few times a week, if not daily. This shows that these smaller manufacturers are in constant contact with their suppliers and customers, which can help to avoid unplanned costs and miscommunication errors. However, even though they frequently exchange data with outside entities, only a few use their design systems to interface directly with the customer or supplier. This may be due to the lack of integration between systems, or in some cases, there is simply no need to have an automated process to exchange data between companies. All interviewees during the first part of the study cited high costs associated with integrating suppliers into their system, and likewise some survey respondents cited high costs to maintain fully integrated systems with their customers. However, these small businesses are still operating as islands of data with manual, more closely scrutinized exchanges of data with outside companies.

Although new research suggests that PDM implementation is most successful when it originates and is managed by the IT group in a larger corporation, most groups in the sample reported that their engineering design systems are managed by their engineering groups (Jackson, 2010). This may be because specific groups of employees dedicated to IT, especially in companies with fewer than 50 people, are difficult to find. However, this may also be a disadvantage because people who are not experts in system management and project management are in charge of such a business-critical system. It is important to mention here, too, that more than a few respondents reported that their design systems were written and maintained internally, implying that their companies do not buy specially designed system software to handle engineering data, but instead they write their own using Microsoft Access or other easily available software development tools. This is an interesting phenomenon that would probably not be seen outside the small business arena.

Contrary to popular belief, a small majority of respondents reported that their design system software, including 3D/2D design tools, was not written by the same software vendor. This may be due to the relatively slow process of adopting technology at small manufacturers and a lack of system planning due to a piecemeal implementation of different business systems (Lee, Bennett, & Oakes, 2000). It could also be because the engineering software industry has yet to produce a truly integrated, cohesive package of software that serves the needs of small and medium manufacturers without being too complicated or expensive.

How PDM systems change the business is one of the most important factors when trying to decipher how the use of these types of systems have affected the companies that have adopted them, which is part of the research question for this study. The last three questions in the survey dealt with how engineering design systems affected collaborative engineering, the use of clearly defined design processes, and whether or not the system met the expectations of the respondent. In a smaller company, each employee has a greater chance to interact with the engineering design system every day than might be seen in a larger corporation, and that level of familiarity may affect attitudes and impressions of the system itself. Most respondents felt that their design system had contributed to concurrent engineering, which is one of the main goals of PDM systems in general. But as an interviewee in the first part of the study pointed out, it is quite possible to use PDM systems in a manner that only further exacerbates the over-the-wall engineering problem. However, most respondents believed that their systems made a moderate or higher contribution to collaborative engineering, showing that these small manufacturers indeed use their systems as they were intended to be used.

CONCLUSIONS

Given the findings in this study, some conclusions can be made about common traits of small manufacturers who have implemented PDM-like systems. First, members of companies who have implemented PDM systems are generally happy with the way these systems have worked for them. They believed their design systems contributed to concurrent engineering, pose little or no restriction on their design method, and met most expectations for what they should be able to do. Locating information is significantly faster, and the system makes doing a design task faster as well, although to a lesser extent. Most of the small manufacturers in the sample exchanged data with outside suppliers and customers at least a few times per week, but this exchange is generally a manual process. The exchange does use neutral file formats extensively, that is, either neutral 3D or 2D file formats. Inside the business, companies share data from their engineering design system with manufacturing systems and purchasing systems, but most do not use workflows as a way to automate the flow of data within the design system. They tend to upgrade their software either every year or every 2-4 years, most likely depending on the nature of their licensing agreement with the commercial software provider, or whether they have created their own homegrown system for managing engineering data. Most companies enter data into their design systems as early as possible and use it throughout the design phase of their products.

In reviewing this study, the researcher came across an interesting revelation: small manufacturers are very enthusiastic about what they do. After the initial survey was sent out, the researcher received several emails from managers and owners of small businesses who were curious about the results of this study. They seemed genuinely interested in this topic because it is an issue they struggle with every day, but in some respects they felt disenfranchised because they rarely have the resources to commit to an extremely robust system. They write their own systems, they do much of their data management manually, and at times they seem to be out of the loop of the ever-advancing manufacturing industry and all its leading-edge technology. Alternatively, they feel that they are at the mercy of their larger original equipment manufacturer (OEM) customers to conform to what the customer requests, often a huge investment in system infrastructure that is burdensome to them. But, they are also the same suppliers and small OEMs that enable larger OEMs to focus their manufacturing efforts on other things. At the federal and academic levels, many programs are in place to help these small businesses thrive, because they truly are one of the driving forces in the U.S. economy. At the same time, there is an acute lack of academic research on these same businesses, including what they are currently doing, what they want to do in the future, and where they fit into the grander scheme of manufacturing economics. This study was mainly concerned with what SMEs are currently doing to manage data in an increasingly digital world where forces beyond their control have started to make them carry out their design and manufacturing in new ways. However, the real question is what this segment of the manufacturing industry will do in the future. How can small manufacturers be enabled to step into the world of PLM and PDM in a way that is cost effective for them but will encourage growth and change while using their unique advantages to help them get ahead? Finally, more research should be conducted that will illuminate more traits of small manufacturers and find better solutions to help address their unique needs.

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References

Ameri, F., & Dutta, D. (2005). Product lifecycle management: Closing the knowledge loops. *Computer-Aided Design & Applications*, 2, 577-590.

Arendt, R. J. (2006). SME-supplier alliance activity in manufacturing: contingent benefits and perceptions. *Strategic Management Journal*, 27(8), 741-763. doi:10.1002/smj.538

Ayyagari, M., Beck, T., & Demirguc-Kunt, A. (2007). Small and medium enterprises across the globe. *Small Business Economics*, 29(4), 415-434. doi:10.1007/s11187-006-9002-5

Chen, S., Huang, J., Yang, C., Lin, W., & Chen, R. (2007). Failure evaluation and the establishment of an improvement model for product data management introduced to enterprises. *The International Journal of Advanced Manufacturing Technology*, 35(1), 195-209. doi:10.1007/s00170-006-0705-1

Dibrell, C., Davis, P. S., & Craig, J. (2008). Fueling innovation through information technology in SMEs*. *Journal of Small Business Management*, 46(2), 203-218. doi:10.1111/j.1540-627X.2008.00240.x

Dillman, D. A. (2007). *Mail and Internet surveys* (2nd ed.). Hoboken, NJ: John Wiley & Sons.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory.* Chicago: Aldine Transaction.

Hicks, B., Culley, S., & McMahon, C. (2006). A study of issues relating to information management across engineering SMEs. *International Journal of Information Management*, 26(4), 267-289.

Jackson, C. (2010). *The CIO's role in PLM*. Aberdeen Business Review. Aberdeen Group.

Lee, G., Bennett, D., & Oakes, I. (2000). Technological and organisational change in small- to medium-sized manufacturing companies: A learning organisation perspective. *International Journal of Operations & Production Management,* 20(5), 549 - 572. doi:10.1108/01443570010318922

Marri, H. B., Gunasekaran, A., & Grieve, R. J. (1998). An investigation into the implementation of computer integrated manufacturing in small and medium enterprises. *The International Journal of Advanced Manufacturing Technology*, 14(12), 935-942. doi:10.1007/BF01179084

Myers, M. D., & Newman, M. (2007). The qualitative interview in IS research: Examining the craft. *Information and Organization*, 17(1), 2-26. doi:10.1016/j.infoandorg.2006.11.001

Philpotts, M. (1996). An introduction to the concepts, benefits and terminology of product data management. *Industrial Management & Data Systems*, 96(4), 11 - 17. doi:10.1108/02635579610117467

Sääksvuori, A., & Immonen, A. (2005). *Product lifecycle management*. Basel, Switzerland: Birkhäuser.

Statistics about Business Size from the Census Bureau. (n.d.). Retrieved February 24, 2009, from http://www.census.gov/epcd/www/smallbus.html

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (2nd ed.). Thousand Oaks CA: Sage Publications.

Towers, N., & Burnes, B. (2008). A composite framework of supply chain management and enterprise planning for small and medium-sized manufacturing enterprises. *Supply Chain Management: An International Journal*, 13, 349-355. doi:10.1108/13598540810894933

Walters, A. (2007). Challenges in managing the convergence of information and product design technology in a small company. Management of Engineering and Technology, Portland International Center for, 799-806. doi:10.1109/PICMET.2007.4349397

The Current State Of Wireless Information Technology In The Construction Industry In Ohio

By Alan Atalah and Aaron Seymour

ABSTRACT

Construction projects are increasingly getting complex and fragmented in nature, yet contractors persistently face shortened project durations and reduced budgets. Timely delivery of accurate and reliable information among all project participants is critical and important because information is the foundation upon which decisions are made and projects are estimated, planned, monitored, and controlled. Recent developments in technology promise to introduce efficiencies that were not previously available to the industry. This study seeks to identify the current state of wireless information technology through the analysis of quantitative data from a web-based survey that represents the views of the respondents on the usage and interest in wireless technology.

The study suggests that the level of interest in wireless technology is much higher than the level of use. Wireless technology enhanced the skills, productivity, and customer service of the participants, but did not improve their ability to negotiate projects and monitor project costs. The respondents believe that the return on investment is not a barrier; slow download speeds and durability are the largest barriers keeping people from using wireless technology.

Keywords: Mobile devices, Web-based project management,

INTRODUCTION

The Internet unquestionably represents one of the most important technological developments in recent history. It has revolutionized the way people communicate with one another, obtain information, and has created an unimaginable variety of commercial and leisure activities (Yoo, 2010). Communication technologies that intimidated many of us just a few years ago are now a part of our daily lives. The wide use of cell phone and the Internet in the early nineties, Hotmail in 1997, Skype in 2004, Twitter and Facebook in 2007 are just a few examples of the changes in the way we conduct our personal and professional lives (Marston, 2011). Technological change increases productivity and economic growth, and the focus should be on how new communication technologies affect business (Wallsten, 2010). Information is the cornerstone of any business process (Stewart & Mohamed, 2004). During the last two decades, a wide range of industries experienced significant productivity improvements because of the technological advancement in information technology, which has provided these industries with great advantages in speed of operation, in consistency of data generation, and in accessibility and exchange of information (Mohamed & Stewart, 2003). The majority of construction business processes rely heavily on traditional means of communication such as face-to-face meetings and the exchange of paper documents in the form of technical drawings, specifications, and site instructions (Deng, H. Li, Shen, & Love, 2001). Wasted time and cost in construction projects can, more often than not, be traced back to inadequate, late, or inconsistent handling of information (Mohamed & Stewart 2003). Construction projects often generate 1 to 2 million pages of documents throughout the course of a job. Without the proper means, retrieving pertinent information from these documents is a time-consuming process for anyone involved with a project (Zack, 2002).

The industry recognizes the need to increase the efficiency of its processes via exchanging massive volumes of information at high speed and at relatively low cost (Deng et al., 2001). Although construction companies seek new solutions to remain competitive in the marketplace, the use of information technology (IT) in construction has not progressed to the level that can be seen in other industries (Flanagan, Ingram, & Marsh, 1998). This is due to a number of historical, industrial, and market forces that have perpetuated the industry's culture and affected the adoption of IT in day-to-day business processes (Baldwin, Thorpe, & Carter, 1999).

Many developments toward the convergence of wireless communications and Internet-based technologies have emerged. Mobile collaboration using wireless networking can be very effective at minimizing the impact of the physical dispersion of project managers and site supervisors (Anumba, Aziz, Bouchlaghem, Carillo, & Ruikar, 2006). Research suggests that reductions in project delivery time of 20 to 50 % are possible when enabling technology improves communication between project participants (Wood & Alvarez, 2005).

Knowledge has been identified to be a significant organizational resource, which if used effectively can provide a competitive advantage. The fragmentation of the construction industry (CI) and ad hoc nature of construction projects provides a challenge for operational communication and information processes. Ultimately, the ineffective capture and reuse of valuable knowledge gathered during a construction project inadvertently contributes to project cost increases and time delays. Given the nature of construction projects, collaborative knowledge management seems to be the most appropriate solution to capture project-based knowledge. Information and communication technologies offer a number of solutions to implement collaborative knowledge management solutions. It is suggested that construction businesses must communicate and exchange information more effectively by adopting IT; the adoption of IT reduces project costs, which in turn provides competitive advantage (Love, Irani, Li, Cheng, & Tse, 2001).

Microsoft, Oracle, Sage, Meridian, Autodesk, HCSS and many others firms have developed web-based construction project management applications for the architecture engineering construction (AEC) industry to collaborate, integrate, communicate, and coordinate construction projects during the last decade. However, many construction organizations still face collaboration challenges, including how to bring extended project teams together across geographical locations, in online and offline environments, and across different technology systems and devices. By providing a rich Web-based user interface on a powerful Web services platform, Web-based project management (WPM) applications allow the project team to collaborate more efficiently and give users flexible choices in how they access critical project data.

Electronic document and project management solutions have increased in popularity as a result of these circumstances. Web-based project management (WPM) allows project participants to access relevant documents through the Internet from virtually any location that has Web access. However, the wired access points that are available through the clients' Internet service provider limit the benefits of WPM. The functionality of WPM and other information technology can be greatly improved by increasing the mobile ability of the Internet through the use of wireless information technology (WIT).

WIT consists of networking hardware and software that significantly increase the mobile access to the Internet by eliminating the need for wired access. This can be done either through a cell phone network with data capabilities or a wireless local area network (WLAN) on local modem or Wi-Fi hotspot. The future of digital communication is mobile; anything and everything will be mobile/wireless (Fleishman Hillard, 2009). A construction workforce that is outfitted with wireless technology could gain mobile access to various critical applications, such as construction management (CM) programs, schedules, cost accounting, and documentation management. Several software providers have adapted construction project management software to run on handheld computing devices, allowing the wireless transmission of data from nearly any location that has access to a wireless data network.

Recent price reductions and improvements in information technology and network speed have allowed many progressive contractors to adopt wireless communications and Internet-based technologies in an attempt to improve communication between the office, the job site, and the client (Anumbaet al., 2006). Small businesses today can get broadband Internet service from many communication companies, for example, Verizon Communications, Time Warner, Comcast, AT&T, and others, for $30 to $90, depending on the speed and the amount of data traffic. Verizon Communications, Time

Warner, Comcast, AT&T, and others offer businesses wireless data plans that cost less than $10/GB. These businesses can bundle Internet services with many other communication services for more savings (Verizon Communications, 2012) (AT&T, 2012). In addition, a wireless modem at the job-site office reliably and securely provides cost effective wireless data communication to the machines on the job site or in the office.

These prices are significantly less than what they were a few years back, and this trend is expected to continue into the future. As the competition among technology giants, such as Apple, Microsoft, Google, Samsung, and others heats up and production exceeds demand, the cost of their devices will be lowered and their capabilities will increase. The same competitive pressure among the retail giants, such as Wal-Mart, Best Buy, and Amazon will lower the cost of these devices (Arora, 2012; Smith, 2012; Zeitlin, 2012). The competitive pressure among communication giants, such as Time Warner, Comcast, AT&T, and Verizon will lower the cost of transferring data among these devices.

The recent release of the National Broadband Plan by the Federal Communications Commission (FCC) has focused the attention of industry leaders, academics, and ordinary citizens on having sufficient bandwidth available anytime and anyplace to support a growing array of broadband services. Broadband services include both wired and wireless access to the Internet and the delivery of high-definition, even 3-D, television (Hatfield, 2010). The FCC's National Broadband Plan recommends that 500 MHz of spectrum be made available for broadband within 10 years, of which 300 MHz should be made available for mobile use within 5 years (Hatfield, 2010).

Many research studies support the enhanced communication, faster decision making, and cost savings that result after initiating information technology solutions (Mohamed & Stewart, 2003). Successfully implementing wireless technology in the CI could streamline many operations of the building process by transcending physical distance when accessing or manipulating information. Significant productivity improvements and shortened project durations could be realized as a result (Menzel & Rebolj, 2004).

Most importantly, adopting WIT can greatly improve the service that is delivered to the owners of projects, as they ultimately receive the benefits. Improved customer service can be realized through customizable Web interfaces that are set up specifically for the project owner to review updated drawings, changes in the schedule, and other project data. The owners' demand for the technology is an important factor in the rate of adoption across the industry. If owners begin regularly requesting advanced technology, then the industry will follow (El-Diraby et al., 2004). Research should focus on the economic effects that digital communications have on specific industries, which are more likely to be identifiable and measurable (Wallsten, 2010); in our case, it is the construction industry.

The use of IT in construction has not progressed to the level seen in other industries (Mohamed & Stewart, 2003) likely because the decision-making process behind investing time and money into wireless communication technologies is poorly understood (Bernold, Lu, & Williams, 2006). After analyzing results of similar studies, one could infer that utilizing an efficient and convenient process of accessing data by means of mobile computing can often-times be overlooked.

AEC industry professionals may be reluctant to consider emerging technology as a way to improve the bottom line for several reasons. Construction companies with accounting or project management software already in place may be hesitant to make a large investment into new software with wireless capabilities that has not been proven to provide cost-saving benefits within their organization. Some may be dissuaded by the perceived barrier of entry that could exist due to additional training, software support, and hardware purchases. Others may be unwilling because of the apparent legal and security complications that could result from the lack of retaining hard copy documentation with signatures of change orders or approvals (Alshawi & Ingirige, 2003). However, contractors must realize that wireless communication technology has become extremely feasible with regard to both setup and cost, and a return on their investment can be achieved in relatively little time (Emborg & Olofsson, 2004). In addition, recent court rulings determined that an official document created, stored, or transmitted electronically can be submitted and verified as evidence in a trial (Zack, 2002).

The main objective of the study was to identify WIT utilization among the employers of the graduates of the CM program at Bowling Green State University (BGSU). The improvements in cost, security, reliability, availability, and capability of mobile communication technology are expected to increase the utilization level significantly in the near future.

As stated previously, the recent advancement in WIT in terms of reliability, speed, and affordability enabled many industries and businesses to achieve higher efficiency, cost savings, and profitability. However, the AEC industry has been slower than other industries in the utilization of these advancements (Mohamed & Stewart, 2003). Learning how the AEC industry uses wireless communication technologies, which ones use them, and the obstacles to using them, will benefit both the AEC industry and the WIT industry. The authors aim to help AEC companies by presenting key factors that should be considered prior to a successful investment and implementation. Software and hardware developers can benefit by gaining insight into the AEC users of WIT for continued product development and improvement.

RESEARCH DESIGN

The employed research instrument was an electronic survey to preselected professionals in the CI. The study population consisted of construction professionals that employed the students and graduates of the CM department in the College of Technology at BGSU. The participants worked for general contractors, subcontractors, and CM firms, and they reflect the construction industry in both Ohio and United States. The subjects were familiar with the CM department, and a good percentage of them were graduates of the department. The respondents' participation in the study was kept completely anonymous, and they were free to withdraw at any time. The results were then analyzed with both descriptive and inferential statistics.

DATA COLLECTION INSTRUMENT

The primary data collection instrument of this study was the voluntary Web-based survey, which is shown in Appendix A. The authors, who are active members of the construction industry, formulated the questionnaires after conducting an extensive review of literature and surveying the available technology in the marketplace and the technologies used in the construction industry. The Human Subjects Review Board (HSRB) at BGSU approved the survey prior to conducting the research. By beginning the survey, the subjects were giving consent to participate in the study, and they were permitted to skip questions or discontinue participation at any time. The electronic survey service anonymously recorded IP addresses to ensure eligible participation and to allow the tracking of unique access without placing a burden on the participant.

Motivating respondents was an important aspect of this study, and the researchers took several steps in order to maximize the response rate and ensure an adequate sample size. In an effort to keep the survey as brief as possible and aid in the final analysis of results, there were no open-ended questions. The invitation to fill in the survey indicated that the survey would take only 10-15 minutes. The questions were designed to be answered with a minimum amount of effort and time for the respondents. The questionnaire consisted of selected-response questions with many including Likert-type rating scales for answers that ranged from strongly disagree to strongly agree as well as numerical ranking scales that ranged from 1 (least) to 5 (most). The questionnaire was worded to be as brief as possible and sought to determine the participants' opinion of the current state of WIT for construction projects in which they had been involved. The survey included questions regarding demographics, industry type, and primary occupation within their construction company.

Four industry professionals were called upon to participate in a pilot test of the survey. The test sample was asked to identify any vague or unclear wording in the document and note suggestions and performance ratings in an evaluation form that was distributed with the test survey. The electronic Web survey was also assessed to ensure proper functionality among those who may not be completely familiar with navigating electronic surveys. At the conclusion of the pilot test, the researchers analyzed the evaluation to identify the necessary enhancement and eliminate any ambiguity from the final instrument.

A week after the launching of the survey, a follow-up reminder was sent to anyone who had not yet completed the survey. The total number of subjects who received the survey request was 298; 62 completed the survey, for a response rate of 20.8%. Anonymous Internet Protocol (IP) addresses were collected and analyzed along with the questionnaire results. It was determined that each response was unique.

FINDINGS AND ANALYSIS OF DATA

The results of the Web-based survey were compiled and exported into Microsoft Excel for formatting and charting purposes prior to using Statistical Analysis System (SAS) software to complete advanced statistical analyses. The Center for Business Analytics at BGSU was instrumental in running a series of inferential statistical analyses such as the chi-square test of independence and Fisher's exact test to investigate the relationships among the categorical variables. The confidence interval of 95% was selected, which is typical for this type of study (Devore, 2011).

Descriptive Statistical Analysis

General Contractors represented 62.9% of the respondents as shown in Table 1.

The subjects whose primary type of construction was Commercial/Industrial represented 56.5% of respondents as shown in Table 2.

Fifty-three of the 62 respondents spent the majority of their time in the office, representing the largest response rate at 85.5%. Those who spent more time in the field represented 14.5% as shown in Table 3.

Table 1. The Primary Business of the Subjects

	Response Count	Response Rate %
General Contracting	39	62.9%
Construction Management	6	9.7%
Subcontractor	6	9.7%
Other	11	17.4%
Total	62	100%

Table 2. Company's Primary Construction Focus

	Response Count	Response Rate %
Heavy/Civil	21	33.9%
Commercial/Industrial	35	56.5%
Residential/Multifamily	6	9.7%
Total	62	100%

Table 3. Majority of Time Spent in Field or Office

	Response Count	Response Rate %
Field	9	14.5%
Office	53	85.5%
Total	62	100%

Out of the 62 respondents, the majority (35) were between the ages of 36-55, which represented 56.5% of the sample population. Only 6 respondents were above the age of 56. Table 4 summarizes the response rate by age.

Table 5 presents the respondents' level of interest in tablet PCs (i.e., iPad, Galaxy, ToughBook, MS Surface, etc.) with mobile construction applications; Smartphones with mobile construction apps; cellular wireless network hardware for laptops (hotspots, wireless cards, etc.); Web-based project management software; GPS tracking software and hardware (location, speed, etc.); and RFID tags (radio frequency identification for tracking materials).

The participants were questioned on how often they accessed Web-based project management software from a wireless device. Of the 59 respondents, those who selected not at all represented the majority, with a 40.7% response rate as shown in Table 6. Thirty-four percent of the subjects used project management software from a wireless device frequently.

The next question, related to the type of business information/applications that the subjects used with a Smartphone or Tablet PC, showed that 94.7% of the respondents selected email; 49.1% and 40.4% of the respondents selected drawings and product information/specifications, respectively as shown in Figure 1. How-to information and videos represented the lowest response rate.

Respondents were questioned regarding how many hours they spent accessing construction-related content on a smartphone or tablet PC on a weekly basis. Table 7 shows that 42.4% indicated that they spent 1-4 hours per week working on construction-related content. Figure 2 shows the percentage of the respondents who used advanced wireless technologies

Table 4. Respondent's Age

	Response Count	Response Rate %
18-35	21	33.9%
36-55	35	56.5%
56+	6	9.7%
Total	62	100%

Table 5. Level of Interest in Wireless Devices

Level of interest in	Score
Tablet PCs with mobile construction apps (i.e., iPad, Galaxy, ToughBook, etc.)	4.03
Smartphones with mobile construction apps	4.15
Cellular wireless network hardware for laptops (hotspots, wireless cards, etc.)	4.31
Web-based Project Management software	3.90
GPS Tracking Software and Hardware (Location, Speed, etc.)	3.46
RFID Tags (Radio Frequency Identification for tracking materials)	2.88

Table 6. Frequency of Accessing Project Management Software from a Wireless device

	Response Count	Response Rate %
Extremely often (multiple times per day)	10	16.9%
Very often (multiple times per week)	10	16.9%
Moderately often (a few times per month)	10	16.9%
Slightly often	5	8.6%
Not at all	24	40.7%
Total	59	100%

such as Field BIM (Building Information Modeling), a handheld wireless scanner with RFID capabilities, digital signature capture, mobile asset management (tools and equipment tracking), wireless security/alarm monitoring, and material management with RFID.

Figure 1. Types of Business Information/Applications Accessed by Respondents (*n*=57).

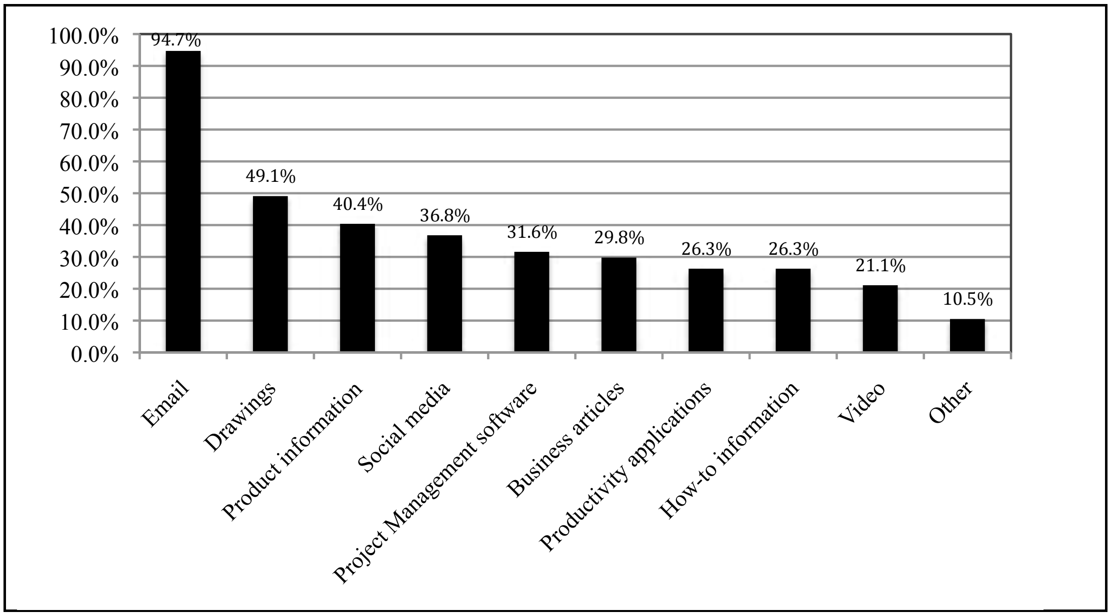
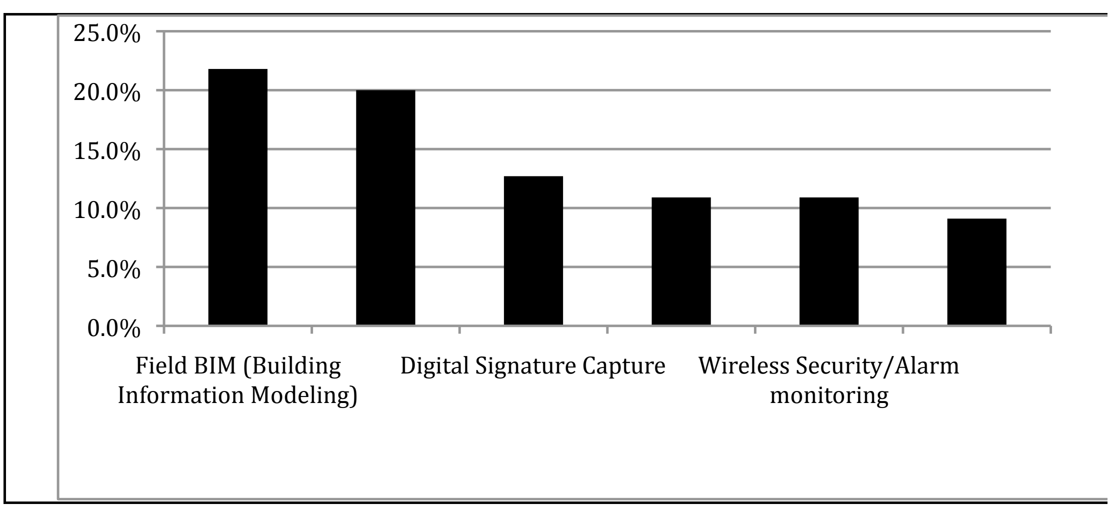


Table 7. Hours Per Week Spent on a Wireless Device

	Response Count	Response Rate %
None	11	18.6
1-4	25	42.4
5-9	14	23.7
10+	9	15.3
Total	59	100%

Figure 2. The Percentage of the Respondents Who Used Advanced Wireless Technologies



The next question sought to identify the respondents' opinion of the barriers to using wireless technology. Table 8 represents the average score on the Likert scale of their responses, which suggests that the return on investment and lack of a clean and stable environment are the main barriers, but they were not very high barriers. Please note that high cost, required training, steep learning curve, and the price of additional wireless service plans are subcomponents of the return on investment.

Table 9 shows the average score for areas of improvement caused by using a smartphone or tablet PC on a scale of one to four; it indicates that the subjects strongly agreed that their use of smartphone or tablet PC improved productivity, customer responsiveness, and collaboration. However, improving their ability to meet tight deadlines, solve problems, make decisions, manage subcontractor/ labor, manage material, manage change orders, and monitor project cost got an average score between 2.60 and 3.00.

Table 10 shows the average score in response to the question related to level of interest in construction functions for which they will use mobile devices.

Table 8. Barriers to Using Wireless Technology

Answer Options	Average score
Little return on investment	3.66
Required training	3.23
Lack of a clean and stable environment	3.23
High cost	3.19
Steep learning curve	3.14
Price of additional wireless service plans	3.05
Lack of security	3.03
High risk of breaking (durability)	2.79
Slow download speed	2.60

Table 9. Areas of Improvement Caused by Smartphone or Tablet PC

My Smartphone or Tablet PC improves my	Average score
Productivity	3.45455
Customer responsiveness	3.32727
Collaboration	3.05455
Ability to meet tight deadlines	2.94444
Problem-solving skills	2.87273
Decision making process	2.81482
Subcontractor/labor management	2.78182
Material management	2.76364
Change order management	2.64815
Ability to monitor project cost	2.6
Ability to negotiate/win projects	2.50909

Table 10. Level of Interest in Constructions for Which They Will Use Mobile Devices

Answer Options	Average Score
Daily reports	3.931034
Safety checklists	3.844828
Quality checklists	3.724138
Punch lists	3.607143
Drawing review/annotation	3.578947
RFI submission	3.464286
Submittal Review and Approval	3.22807
Timesheet tracking	3.192982

Figure 3 shows the responses regarding their expectations of purchasing wireless software or hardware in 2012 relative to 2011. The graph suggests that the highest investment is going toward smartphones, tablet PCs, and construction-related mobile applications.

Figure 4 shows the construction applications for which the subjects used smartphones or tablet PCs; they mostly used them for email, document management, and daily reports

Figure 3. Expectation to Purchase More, Less or the Same Dollar Amount of the Following Items During 2012 Versus 2011

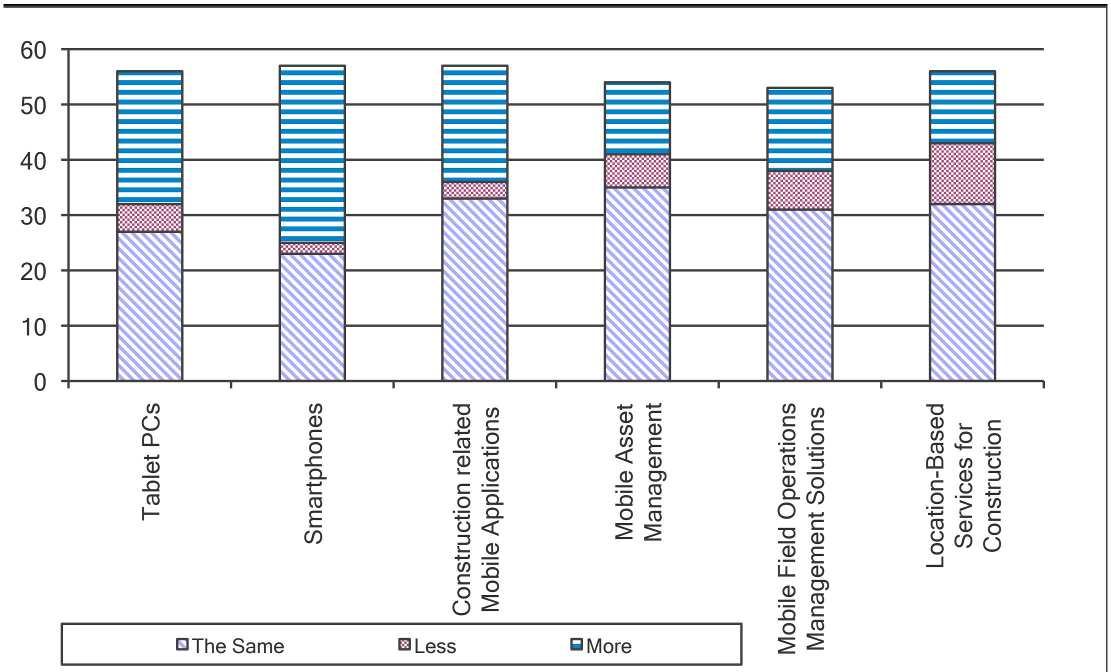
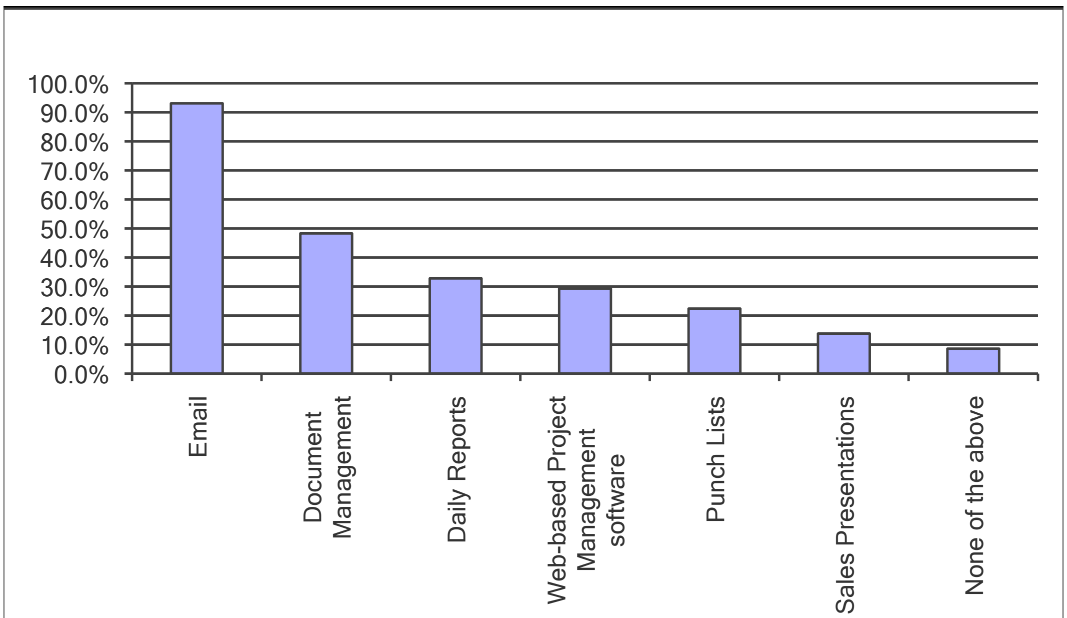


Figure 4. The Construction Applications for Which the Respondents Used a Smartphone or Tablet PC



CONCLUSION AND RECOMMENDATIONS

While interest levels among respondents were high, the results of the research study revealed several areas that should be improved before significant progress can be achieved. In summary, 72.1% of respondents indicated a high level of interest in tablet PCs, smartphones, and wireless hotspots; 59.3% of respondents indicated high interest in mobile applications that can complete daily reports, safety checklists, and quality checklists. The analysis suggests a discrepancy between the interest and usability of WPM software; 67.2% of respondents indicated a high interest in using WPM software on a wireless device, but 66.1% are only accessing project management information from wireless devices a few times per month or not at all. Wireless technology was found to enhance the skills, productivity, and customer service of the participants, but it did not improve the respondents' abilities to negotiate projects and monitor project costs.

The respondents shed some light on the barriers to wider implementation of wireless technology in the CI. Slow download speeds and durability in the rough construction environment were the largest barriers that kept people from using wireless technology. It is anticipated that the widespread use of 4G LTE and protective gear (such as ruggedized cases) will alleviate these barriers. The respondents indicated that a return on their investment in wireless technology was not a primary barrier. Interactive, online collaboration will someday be commonplace among project teams, and companies will need to create more flexible organizational roles.

The analysis of the results showed no significant difference in the level of interest among the participants whose primary business was heavy, commercial, or residential construction. However, individuals in the heavy/civil specialization reported a statistically significant higher use of mobile technology. There was not a statistically significant difference between the level of interest and use among the field and office subjects. As expected, the respondents in the age group of 18-35 used wireless technology more than the group of individuals over the age of 36; however, there was no significant difference between these groups when compared against their interest in wireless technologies. This suggests that technology interest and use is becoming less dependent upon age. As expected, the respondents who spent more time per week on their wireless device realized an improved synergistic effect on productivity and customer service skills than the group who spent less time on their wireless device.

Tablets will outsell laptops in 2013, with over 240 million units to be sold worldwide, as it is no longer the exclusive domain of Apple. Lenovo, Samsung, Toshiba, and many other leading firms introduced their own tablets. There are interesting battles brewing on whether the tablets will be powered by ARM, Intel, or AMD processors and whether the operating system will be Apple iOS, Google Android, or Microsoft Windows. These choices are good for buyers as the tablets become more optimized for specific uses such as retail point of sale (POS) or enterprise sales force tools (Ellett, 2013). Developers of WPM and other construction management software need to create a responsive design to make these programs accessible and user friendly on both tablets and PCs.

The following recommendations for future study are offered:

- This study should be repeated periodi cally to evaluate the impact of future developments in wireless technology on the CI.
- Some open-ended questions should be incorporated into a questionnaire to gain a better understanding of the motiva tions behind the answers.
- The CM departments at BGSU and other universities should adjust, if needed, the construction curriculum to prepare the students better for the future digital construction world.
- Additional survey research should be conducted on a bigger sample of re spondents that include representative of different types of construction, geo graphical locations, sales volumes, field professionals, and so forth.

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REFERENCES

Alshawi, M., & Ingirige, B. (2003). Web-enabled project management: An emerging paradigm in construction. *Automation in Construction*, 349-364.

Anumba, C., Aziz, Z., Bouchlaghem, D., Carillo, P., & Ruikar, D. (2006). Intelligent wireless web services for construction – A review of the enabling technologies. *Automation in Construction*, 113-123.

Arora, N. (2012, December 17). *Wal-Mart tosses Apple into The discount bin*. Retrieved from http://www.forbes.com/sites/greatspeculations/2012/12/17/wal-mart-tosses-apple-into-the-dis count-bin/

AT&T. (2012). *Data & Internet Services*. Retrieved from http://www.att.com/shop/wireless/services/data-internet.html

Baldwin, A., Thorpe, A., & Carter, C. (1999). The use of electronic information exchange on construction alliance projects. *Automation in Construction*, 651-662.

Bernold, L., Lu, H., & Williams, T. (2006). T*he state-of-practice and the future of information technology in construction 2005. ASCE-CI Committee on Wireless Construction*, Retrieved from http://www.constructioninst.org/committee/?ode=SVhDTTYwM

Deng, Z., H. Li, C. T., Shen, Q., & Love, P. (2001). An application of internet-based project management system. *Automation in Construction*, 239– 246.

Devore, J. L. (2011). *Probability and statistics for engineering and the sciences* (8th ed.). Duxbury Press.

El-Diraby, T., Froese, T., Mora, R., Munir Gill, S., O'Reilly, T., Rivard, H., . . . Waugh, L. (2004). Case studies on the use of information technology in the Canadian construction industry. *Journal of Information Technology in Construction,* 9, 19-34.

Ellett, J. (2013). *CES highlight #2: Tablets*. Retrieved from Forbes.com LLC™: http://www.forbes.com/sites/johnellett/2013/01/10/ces-highlight-2-tablets/

Emborg, M., & Olofsson, T. (2004). Feasibility study of field force automation in the Swedish construction sector. *Journal of Information Technology in Construction*, 285-295.

Flanagan, R., Ingram, I., & Marsh, L. (1998). *A bridge to the future: Profitable construction for tomorrow's industry and its customers.* London: Thomas Telford.

Fleishman Hillard. (2009 , May 15). *My half time pep talk for 2009/The future of digital communications*. Retrieved 1 from http://innovation.fleishmanhillard.com/index.php/2009/05/15/my-half-time-pep-talk-for-2009the-future-of-digital-the-greatest-innovation-of-all-time/

Hatfield, D. N. (2010). The challenge of increasing broadband capacity. *Federal Communications Law Journal*, 43-63. Retrieved from Time Warner Cable Research Program on Digital Communications.

Love, P., Irani, Z., Li, H., Cheng, E., & Tse, R. (2001). An empirical analysis of the barriers to implementing e-commerce in small-medium sized construction contractors in the state of Victoria, Australia. *Construction Innovation: Information, Process, Management*, 1 (1), pp. 31-41.

Marston, L. (2011, May 26). *The future of digital communications*. Retrieved from http://www.nesta.org.uk/assets/blog_entries/the_future_of_digital_communication

Menzel, K., & Rebolj, D. (2004). Semantic web based services for intelligent mobile construction collaboration. *Journal of Information Technology in Construction*, 9, 367.

Mohamed, S., & Stewart, R. A. (2003). An empirical investigation of users' perceptions of web-based communication on a construction project. *Automation in Construction*, 12 (1) 43-53.

Smith, D. (2012, December 18). *Apple iPhone 5 price drops To $127 at Walmart; iPad 3 selling with $100 Discount*. Retrieved from http://www.ibtimes.com/apple-iphone-5-price-drops-127-walmart-ipad-3-selling-100-discount-945104

Stewart, R., & Mohamed, S. (2004). Evaluating web-based project information management in construction: Capturing the long-term value creation process. *Automation in Construction*, 13 (4), 469-479.

Verizon Communications. (2012). *Verizon Wireless Business Plans.* Retrieved from http://business.verizonwireless.com/content/b2b/en/shop-business-products/business-plans.html

Wallsten, S. J. (2010). *The future of digital communications research and policy*. Washington, DC: Technology Policy Institute.

Wood, C., & Alvarez, M. (2005). *Emerging construction technologies: A FIATECH catalogue*. Gaithersburg, Md.: National Institute of Standards and Technology.

Yoo, C. S. (2010). The changing patterns of Internet usage. *Federal Communications Law Journal*, 68-86.

Zack, J. G. (2002). Electronic project documentation: Legal and practical problems. *AACE International Transactions*, pp. CDR.06.1-CDR.06.6.

Zeitlin, M. (2012, December 18). *Behind Apple's big stock decline*. Retrieved from http://www.thedailybeast.com/articles/2012/12/18/behind-apple-s-big-stock-decline.html

Appendix A
Survey – Current State of Wireless Technology

1. Please indicate your company's primary business?

o General Contracting	o Construction Management	o Architectural/Engineering	o Subcontractor

2. Please indicate your company's primary construction focus? (please check one)

o Heavy/Civil	o Commercial/Industrial	o Residential/Multifamily

3. Is the majority of your time spent in the field or in the office?

o Field	o Office

4. How old are you?

o 18-35	o 36-55	o 56+

5. How much interest do you have in using the following wireless technologies using a scale of 1 (least) to 5(most)? If no interest or previously unaware of the product, please check "N/A." If you already own a product, please mark "Own."

	1(least)	2	3	4	5	N/A	Own
• Tablet PCs with mobile construction apps (iPad, Galaxy, ToughBook, etc.)							
• Smartphones with mobile construction apps							
• Cellular wireless network hardware (hotspots, wireless cards, etc.)							
• Web-based Project Management software							
• GPS Tracking Software and Hardware (Location, Movement, Speed, etc.)							
• RFID tags (Radio Frequency Identification for tracking materials							

6. How often do you access web-based project management software from a wireless device?

o Extremely often (Multiple Times per day)	o Very Often (Multiple Times per week)
o Moderately Often (A few times per month)	o Slightly Often
o Not at all	o

7. What type of Business information/applications are you accessing with a Smartphone or Tablet PC? (please check all that apply)

o Email	o Web-based Project Management software
o Productivity applications	o Drawings
o Product information/specifications	o How-to information
o Video	o Business articles
o Social media (Business Purposes Only)	o Other____________________________________

8. **How many hours/week do you spend accessing construction content on a smartphone or Tablet PC?**

o None	o 1-4	o 5-9	o 10+

9. Please indicate the severity of barriers to using Wireless Technology on a scale of 1 (is a significant barrier to use) to 5 (not a barrier at all) for each of the following:

	1(barrier)	2	3	4	5(not a barrier)
• High cost					
• High risk of breaking (durability)					
• Slow download speed					
• Steep learning curve					
• Lack of security					
• Required training					
• Little return on investment					

	1(barrier)	2	3	4	5(not a barrier)
• Lack of a clean and stable environment					
• Price of additional wireless service plans					

10. My Smartphone or Tablet PC improves my

	Strongly Agree	Agree	Disagree	Strongly Disagree
• Productivity				
• Problem-Solving skills				
• Material management				
• Subcontractor/Labor Management				
• Decision-making process				
• Ability to meet tight deadlines				
• Collaboration				
• Customer Responsiveness				
• Ability to Negotiate/Win Projects				
• Ability to Monitor project cost				
• Change Order Management				

11. During 2012, do you expect to purchase/receive more, less or the same dollar amount of the following items? (versus the same period in 2011):

	More	Less	The Same
• Tablet PCs			
• Smartphones			
• Construction related Mobile Applications			
• Mobile Asset Management			
• Mobile Field Operations Management Solutions			
• Location-Based Services for Construction			

12. On a scale of 1 (least) to 5 (most), how much interest would you have in using the following mobile apps?

	1(least)	2	3	4	5(most)
• Timesheet tracking					
• Punch Lists					
• RFI submission					
• Submittal Review and Approval					
• Daily Reports					
• Quality Checklists					
• Safety Checklists					
• Drawing Review/Annotation					

13. I have used a smartphone or Tablet PC for the following: (please check all that apply)

o Sales Presentations	o Document Management
o Email	o Web-based Project Management software
o Punch Lists	o Daily Reports
o None of the above	o

14. I have used the following advanced wireless technology (please check all that apply)

o Mobile Asset Management (tools and equipment tracking)	o Material Management with RFID
o Handheld wireless scanner with RFID capabilities	o Field BIM (Building Information Modeling)
o Wireless Security/Alarm monitoring	o Digital Signature Capture
o None of the above	o

Addressing Safety and Liability in STEM Education: A Review of Important Legal Issues and Case Law[1]

By Tyler S. Love

ABSTRACT

Labs of today are less safe, students are inadequately instructed in safety, and faculty members do not have adequate experience to lead students safely (Haynie, 2008). Technology education, career and technical education (CTE), industrial education, engineering education, and science education laboratories are potentially dangerous places, which is why faculty members working in these areas must not only be concerned with student and faculty safety, but also protection against their own liability (Gathercoal & Stern, 1987; Frantz, Friedenberg, Gregson, & Walter, 1996; Hall & Marsh, 2003; Toglia, 2009). Injuries resulting from school laboratory activities are a harsh reality due to the hands-on design-based learning that is the cornerstone of science, technology, engineering, and mathematics (STEM) education. Despite potential injuries, STEM educators cannot fear liability and sacrifice the advantages of laboratory experiences that foster inquiry-based science and are essential to student learning (Zirkel & Barnes, 2011).

Studying and following developing case law can serve as a viable means for institutions, administrators, and faculty members potentially to prevent an accident and to avoid being found liable. STEM education teacher preparation programs must adequately prepare pre-service and in-service teachers and administrators through coursework, professional development, and developing case law. Being proactive about potential litigation will save time, money, and other costly measures that are important considering today's tight budgets and trying to prevent losses (Janosik, 2005). This article examines current legal cases regarding classroom and laboratory safety issues for grades P-16 STEM education programs. In addition, strategies for managing these risks and reducing liability will be discussed.

Keywords: STEM education, liability, case law, safety, technology education

BACKGROUND

Integrative science, technology, engineering, and mathematics (STEM) education is defined as, "the application of technological/engineering design based pedagogical approaches to intentionally teach content and practices of science and mathematics education concurrently with content and practices of technology/engineering education. Integrative STEM education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels" (Wells & Ernst, 2012, para. 2). Therefore, in this article technology, engineering, and design education (TED) will encompass technology education, CTE, and industrial education to represent the T in STEM due to their considerable amount of (intentionally) integrative instruction (Herschbach, 2011), their curricular alignment with STEM initiatives (Asunda, 2011), and their high risk of liability (Frantz et al., 1996). This article examines current legal cases regarding classroom and laboratory safety issues for grades P-16 STEM education programs. In addition, strategies for managing these risks and reducing liability will be discussed.

The Utah Department of Health (2007) reported that on average, 160 students are injured and 86 school days are missed because of school shop (laboratory) injuries every school year in the state of Utah alone. The most common piece of equipment involved in school laboratory injuries was the band saw, which accounted for 13% of the reported injuries (Utah Department of Health, 2007). Also, laboratory safety extends beyond the school building to workplaces where students apply their educational experiences. Storm (1993) drew many parallels between safety in school laboratory settings and industry, specifically financial and productivity losses resulting from an accident. The National Institute for Occupational Safety and Health (Bergeson et al., 2002) reported that every year 6,000 Americans die from workplace injuries, 6 million people suffer from nonfatal workplace injuries, and injuries alone cost the U.S. economy more than $110 million. An incident could occur at any institution or school; thus, it is a best practice to remain proactive about legal issues (Janosik, 2005) related to STEM education.

Current TED laboratories use smaller scale equipment that is less powerful and intimidating than machines used during the industrial arts era (Haynie, 2009). Despite not being as powerful or intimidating, faculty members (all educators) and students may not be properly trained in their safe operation, resulting in injuries and lawsuits. Haynie (2008) believes that "The labs of today are less safe, the students of today are inadequately instructed in safety, and the teachers of today simply do not have adequate experience with equipment to lead students safely" (p. 97). This risk poses a threat to students, faculty members, administrators, institutions, and school districts. To avoid being found liable, administrators and faculty members in STEM education teacher preparation programs should stay informed regarding the latest lawsuits occurring in STEM education classrooms at the P-16 grade levels.

LITERATURE REVIEW

The common misconception of administrators and faculty members is that these type of accidents (e.g., eye injuries, lacerations, amputations, and other permanent injuries resulting from STEM education classroom and laboratory activities) will not happen to them or occur at their school (Pennsylvania Department of Education [PDE], 2012). The reality is that these accidents occur at all types of schools more often than administrators and faculty would like to believe. In 2007 Barrios, Jones, and Gallagher conducted a study analyzing 455 cases from 1996-2002 in which P-12 schools or school districts were sued for an injury sustained on school property. They found that on average, cases took nearly four years from incident to trial or settlement. Approximately two thirds of the cases resulted in schools paying an award because of a verdict directed for the plaintiff or a settlement. The mean award was $562,915, although Barrios et al. (2007) admitted that the award amounts were highly skewed.

Barrios et al. (2007) cautioned that the percentages of injuries and settlements retrieved by their legal research database are likely to be smaller than the published numbers because many cases are settled before being filed with a court. Despite settlements being underrepresented, they still account for the most common outcome representing the decision in 40% of the cases. Laboratory or shop injuries were the second least common activity to cause an injury lawsuit, only accounting for 7.6% of the cases. Although this number seems small, it still accounts for permanent injuries and consumption of time and money for the school, which was reported in the mean award amount. The majority, almost 80%, of the injuries occurred to students. About 58% of the time the injury resulted from the negligence to properly supervise. Barrios et al. (2007) reported that amputation resulted in the least amount of cases, but had a mean award of about $1 million. Tendon, cartilage, or ligament damage occurred 5.9% of the time, with a mean reward of about $300,000, and lacerations occurred 10.6% of time, resulting in a mean award of about $230,000. Although this data summarizes injuries within P-12 schools, it shows the significance to proactively prepare pre-service and in-service teachers to be properly trained in safety and liability issues. Despite the permanent damage to the student, it will cost the defendant hundreds of thousands of dollars, sometimes millions. Administrators and faculty members can save countless hours, headaches, and dollars by understanding the law and researching case law to implement precautionary safety measures.

The current educational reform movement has been calling for the integration of STEM education (National Commission of Excellence in Education [NCEE], 1983; American Association for the Advancement of Science [AAAS], 1989; AAAS, 1993; AAAS, 2011; International Technology Association [ITEA/ITEEA], 2000/2002/2007; National Research Council [NRC], 2012). A related question is, who is adequately trained to teach this content in a safe and integrative manner (Wells, 2008)? Most recently, A Framework For K-12 Science Education: Practices, Crosscutting Concepts, And Core Ideas (NRC, 2012) explicitly calls for integrating engineering concepts within the science curriculum. Although hand

and power tools are routinely used by TED teachers to implement engineering concepts in the curriculum, science educators need more instruction in hazard recognition and safety training (Roy, 2012) to successfully implement design-based engineering content using these tools.

TED educators play a vital role in delivering integrative instruction (ITEA/ITEEA, 2000/2002/2007), and Sanders (2012) suggested that they should play a prominent role in delivering integrative STEM literacy. Because most educators are not adequately prepared to teach STEM education simultaneously, collaboration among STEM education instructors is the most promising approach for implementing integrative practices (Wells, 2008).

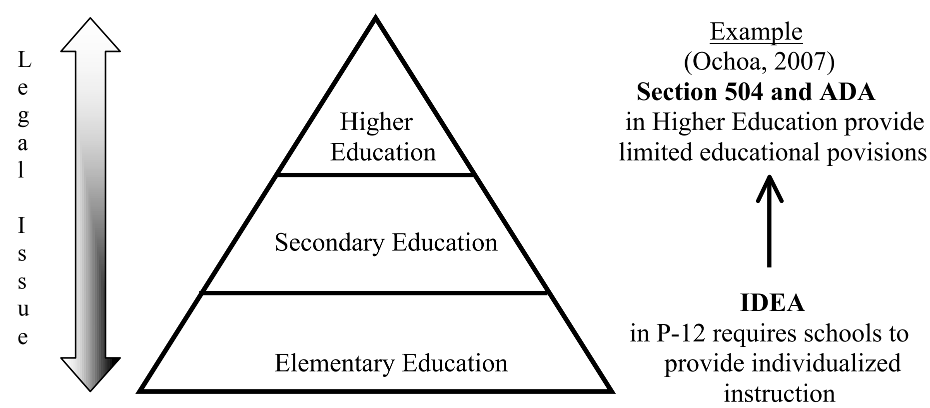
Minors and Adults on College Campuses

Paying attention to changes in the law and following case law resulting from employee and institutional liability is critical in anticipating and planning for potential issues. Employees in higher education may also benefit from following litigation at the P-12 level. Litigation beginning at one educational level may emerge or evolve into legal issues at another educational level. Figure 1 displays the way legal issues can start at one level of the educational continuum and work up to higher education or down to secondary and elementary education (Janosik, 2005).

Janosik (2005) cautioned higher education employees to interpret P-12 case law with great care. Judges will draw differences between P-12 children who are normally minors and are required to participate in schooling until the age of 16 and college students who are legal adults if 18 years or older. Students who are legal adults are usually deemed able to think for themselves and can exercise free choice (Janosik, 2005). The lines become blurred when a college freshman is 17 years old (still a minor) despite the majority of students at an institution being legal adults. A different legal process and care of duty may be applied toward minors.

At the P-12 1evel, faculty members assume some of the rights and duties of the parents, also known as in loco parentis (Kigin, 1983). However in higher education, and sometimes in secondary education, in loco parentis is not applicable because of the age and maturity of the students (Hall & Marsh, 2003). Paying attention to the case law for both minors and adults may prove beneficial. Knowing the law for students with disabilities will also be helpful, because

Figure 1. Safety and Liability in STEM Education



Anticipating legal issues in Education. Legal issues on the left can move up or down the educational continuum in the triangle. The example on the right shows future implications to provide more provisions for students with disabilities, which is slowly emerging from P-12 into higher education. Adapted from personal communication with S.M. Janosik, September 13, 2012.

these students may require a care of duty regardless of age and special accommodation. Legal rulings at the higher education level may differ from those at the P-12 level; however, important information can be drawn from examining rulings at both levels.

Tort Liability

Injuries to students in a STEM education classroom are classified as tort liability, also referred to as tort law. Kaplin and Lee (2007) define tort law as follows:

> A civil wrong, other than a breach of contract, for which courts will allow a remedy. A tort claim generally involves allegations that the institution, or its agents, owed a duty to one or more individuals to behave according to a defined standard of care that the duty was breached, and that the breach of that duty caused injury to the individual(s) (p. 87).

Although tort liability has a broad range, negligence is the most common claim brought against institutions and faculty members for injuries sustained in a STEM education classroom (Toglia, 2009). In addition, Ferguson, Ford, and Bumgarner (2010) claimed that common tort cases involving higher education institutions are instructor negligence in laboratory settings. Negligence occurs when an employee or institution breaches the duty to protect students from foreseeable harm, if an employee or institution fails to act on a situation, or if an employee or institution's actions contributed to the plaintiff's injury (Owen, 2007). An institution is generally liable for tortious acts committed by employees acting within the scope of their job responsibilities. For example, if a student, an employee, or an invitee (an individual that an institution entitles or permits to be on its property) is injured as a result of a careless or wrongful act of an employee, the institution may be liable (Kaplin & Lee, 2007).

When students or other invitees are injured resulting from on-campus instructional activities, they may file negligence claims against either the institution or the employee. Individual employees may be liable if they committed the tortious act, directed it, or participated in its commission. Both the employee and institution may be liable if an employee commits a tort while representing the institution and is acting within the scope of the authority delegated by the institution. However, an employee may be personally liable and the institution not liable if the employee committed a tort while acting outside scope of delegated authority (Kaplin & Lee, 2007).

Strict liability is another type of tort that can be brought against either an institution or its employees. Strict liability is defined as, "the legal responsibility for damages, or injury, even if the person found strictly liable was not at fault or negligent" (Batten, 2010, p. 403). This means that the defendant (institution or employee) could be found not responsible, but asked to pay the plaintiff to make up for the loss in the incident.

The Shotgun Theory of Litigation

In a tort lawsuit, the plaintiff's attorney will frequently use "shotgun litigation." In this case, the plaintiff will file suit against "anyone even remotely connected to an incident to ultimately find a 'deep pocket' defendant liable or to force a settlement from that deep pocket even when there is no liability" (Phillips, 1986, p. 699). This could involve bringing suit against the institution, administrators, employees, third-party companies (e.g., machine manufacturer), and possibly other students. The judge will determine who can be put on trial. The motive for plaintiffs to sue anyone involved is to find someone who is liable and will owe money to the plaintiff. Administrators or employees at an institution may find their names in a lawsuit even if they were not directly involved. It is important for administrators and employees to be aware of what is going on at their institution so they do not end up being found liable for an incident that they could have prevented.

Immunity is Not Always an Option

Immunity means that the institution or employee cannot be sued according to state statutes. Many employees are misled into believing that they are shielded from lawsuits due to governmental or sovereign immunity. Immunity is narrowly defined and has numerous exceptions (Toglia, 2009). Even in the case where governmental immunity is granted to an institution, students may still sue individual employees for their negligence (Schimmel, Fischer, & Stelleman, 2008).

For example, under section 8541 of the Pennsylvania Judicial Code (1980), local government agencies (such as schools) are generally immune from tort liability; however, this is not absolute. Section 8542 of the Pennsylvania Judicial Code (1980) states that an injured party may recover in tort from a local agency if there is negligence in several areas. One of those areas is real property, which refers to the buildings or fixtures on the government agency's property. Fixtures can sometimes refer to equipment in a STEM education laboratory as is shown in the cases described later in this article. Real property negligence is not applicable where there is no defect or condition of the agency's real property that causes an injury. This interpretation of governmental immunity will also be seen in many of the cases presented later in this article.

Immunity laws are different in every state, so it is important for employees and institutions either to thoroughly understand the laws in their area (Roy, 2009) or to seek legal counsel to make sure they are in compliance with the laws. Ignorance is not a defense against a tort liability suit. Because governmental immunity is not always applicable, employees and institutions must educate themselves and others on how to avoid being negligent and found liable. One way to avoid being found liable is to review case laws and make the proper adjustments at one's institution.

CASE LAW

Lawsuits relating to STEM education programs and facilities can be found in the newspaper, scholarly journals, and in academic legal research databases, as shown in Table 1. It is seemingly impossible for an individual to research every case related to STEM education, so Janosik (2005) suggested nine methods to stay abreast of important legal cases (Table 2).

Examining STEM Education Case Law

One of the fundamental cases in science education liability is Usher v. Upper Saint Clair School District (1985). In this case an instructor dropped a chemical beaker that splashed flaming fluid on a student's face. The student (Usher) alleged that the instructor was negligent in failing to take adequate measures to control the area surrounding the experiment. The court ruled that the instructor failed to control the students, not the area of the experiment; therefore, immunity was granted to the instructor and the school.

Eleven years later an accident at Georgia Tech occurred (Niles v. Board of Regents, 1996) when a doctoral student sustained injuries resulting from mixing chemicals inside a metal canister that exploded. The student graduated summa cum laude with an undergraduate degree in chemistry and spent hundreds of hours in the lab prior to this incident. The student sued Georgia Tech and the Board of Regents, but the

Table 1. Sources for Finding STEM Education Case Law

Source	Example(s)
In The News	Local and national newspapers, professional association newsletters, radio, local and national television news stations.
Scholarly Journals	*The Chronicle of Higher Education* *Science Teacher* (published by NSTA) *The Technology and Engineering Teacher* (published by the ITEEA) *Journal of School Health* *NASPA Journal* Other journals not listed
Academic Legal Research Databases	FindLaw (a free resource) – (Thomson Reuters, 2013a) LexisNexis – (Reed Elsevier Inc., 2013) Westlaw – (Thomson Reuters, 2013b)

Table 2. Staying Abreast of Important Legal Cases

Method	Action
Seek Expert Advice	Use expertise of others at your institution (e.g., attorneys, risk managers)
Subscribe to Periodicals	Invest in high-quality periodicals that address contemporary strategic issues.
Identify Topics	Create a manageable list of hot topics.
Involve Staff	Delegate responsibilities to include staff.
Search the Internet	Use the internet to search effectively.
Monitor Agendas	Follow the activities of federal, state, and local officials to identify shifts in agendas.
Follow Groups	Track the activities of special interest groups.
Network with Others	Build personal networks with informative people.
Share New Findings	Disperse new legal developments in a brief and effective manner.

court ruled in favor of the Board of Regents. They claimed that neither the university nor the professor were required to warn the student about mixing chemicals since he had a degree in chemistry, and there was no evidence that a lab safety course would have prevented the accident.

Fast-forward another 13 years to another case (Heuser ex rel. Jacobs v. Community Insurance Corporation, 2009) in which an eighth grade student sustained a cut while using a scalpel to dissect a flower in science class. His parents sued the school for negligence because he was the third student that day to sustain a cut from a scalpel in that class. The court ruled in favor of the student, finding that no precautionary measure was taken in response to the open and obvious danger of the scalpels. The instructor had the option to pick one precautionary measure over another but instead chose to do nothing, resulting in the school district being found liable.

A more recent case (Grammens v. Dollar, 2010) involved another eighth grade student in a science class who suffered an eye injury while launching a two-liter soda bottle with water and air pressure. When the bottle lifted off the launch pad and the student removed the pin that held the bottle in place, the pin struck the student in the eye. The student's father sued the instructor, the school principal, and the school superintendent, alleging the injury was the result of a violation of the county board of education's eye protection policy. The trial court granted immunity to all of the defendants because the negligence claims were discretionary and protected from personal liability under official immunity. The Court of Appeals agreed that the superintendent and principal qualified for immunity; however, it ruled the instructor should not be granted immunity because the eye protection policy was mandatory, not discretionary. On appeal, The Supreme Court of Georgia ruled that because the term "explosive materials" did not appear in the county's eye protection policy, it was the instructor's discretion to use safety glasses for the bottle rocket activity and the instructor was granted immunity from personal liability. The school district was encouraged to rewrite their safety glasses policy with greater detail.

There have been many cases involving TED education due to the nature of the high-risk equipment used in the profession. One case (Fontenot v. State ex rel. Department of Education, 1994) involved the student's father suing the State of Louisiana Department of Education, Pelican Mutual Insurance Company, Horace Mann Insurance Company, the instructor, and the school board for a table saw accident that injured his 14-year-old son who had special needs. The instructor had demonstrated the use of the table saw and observed students individually to ensure that they had mastered skills in its use. The student (Fontenot) was adjusting the guide fence when someone distracted him by calling his name, causing his hand to slip into the still-turning blade. The instructor had not left his immediate teaching area or abandoned his supervisory duty. The instructor and his insurer settled with the Fontenots. Fontenot's father also brought suit against the school for placing his son in a class that was not appropriate for his son's disability, but the court ruled his son was appropriately placed.

In 2002, Cureton v. Philadelphia School District, involved a 13-year-old student (Cureton) who permanently disfigured his right index finger while cleaning a scroll saw. The instructor informed students to keep the machines clean, and Cureton was granted permission to clean the saw. After cleaning the saw, Cureton reached across the saw and turned it on, which resulted in his untucked shirttails getting caught in the saw's pulleys. The pulleys amputated a portion of his finger, which was surgically repaired at a local hospital despite the student suffering permanent deformation and scarring. Cureton's mother originally filed a product liability suit, which she later changed to negligence claims against the school district. The court ruled that the scroll saw was real property and not personal property since the saw was in place since 1987, permanently hardwired through the building, bolted to the floor, and was never removed from the shop. The court used the ruling from Usher v. Upper St. Clair School District (1985) to determine if the negligence was the result of the real property (the saw) or was simply a cleaning accident that went awry. The court found the school district liable since the instructor neglected to turn the main power off when there was foreseeable danger. The instructor gave permission and responsibility to the student to clean the saw, and on prior occasions the teacher turned the power off, but not on this occasion. The school district argued that Cureton was able to comprehend danger and should have known better, but failed to present evidence showing that he was negligent because other classmates did or would do the same thing when cleaning the machine. Cureton was awarded $35,000.

Three years later in Wells v. Harrisburg Area School District (2005) an 11th grade student experienced a kick back on a table saw that hit him in the stomach, causing him to lose his balance and place his hand over the blade. He lost his ring finger, the tips of his thumb and small finger, and sustained serious injury to his middle finger of his left hand. The student was told that the guard could not be used when performing this type of cut, however expert testimony showed that another guard could have been purchased and used during a groove cut for that particular saw. The instructor and district engaged in negligent care by allowing novice students to use a table saw that lacked an adequate safety device. Therefore the court ruled that the school district created a dangerous condition of the real property (table saw) that caused the student's injuries. The student was awarded $240,000.

Just one year later in another Pennsylvania case, LoFurno v. Garnet Valley School District (2006) a 15-year-old 9th grade student caught his fingers on both hands between the belt and table while operating a vertical belt sander. The student (LoFurno) allegedly suffered permanent damage to his right and left index fingers. His parents sued the school claiming that the belt sander was a fixture (real property) with no safety guards or warnings on the sander, and also negligence for not properly supervising and instructing its employees on the proper use of dangerous equipment. The court ruled the sander as real property, but on appeal the decision was reversed. The appellant court granted the school district immunity, ruling that the sander was not realty because it was not bolted down, it could be plugged into any outlet in the room, and the dust collection hose was removable.

Learning from Case Law

Many of the cases presented involved middle and high school students whose parent or guardian brought suit against the school because these people were financially responsible for the medical bills of that child. Contributory negligence was used as a defense in Niles v. Board of Regents (1996) because the court looked at the student's age and experience in the chemistry lab to decide that he was negligent for performing a task he should not have performed. This defense may not have been valid if the student were a minor or had little experience in the chemistry lab. The variety of tools and processes that brought about these lawsuits shows the vast range of safety preparation and knowledge that STEM educators must possess. Roy (2011) emphasized the importance of educating pre-service and in-service teachers about how to safely use and teach about the tools in the lab.

These cases illustrate that no case is clear-cut. A great deal depends on the evidence presented and precautions taken by the institution and the faculty member. Many of the defendants in the Pennsylvania cases were granted immunity when a piece of equipment was deemed personal property or realty under state law. In Cureton v. Philadelphia School District (2002) the court ruled the scroll saw was real property, but in LoFurno v. Garnet Valley School District (2006) the school's belt sander was not deemed real property. The arguments the defendants in Garnet Valley School District case used to establish their belt sander as personal property were different than the arguments used in the Cureton case. The significance of the LoFurno case is it now allows school attorneys an opportunity to cite it when trying to obtain immunity by proving a machine is not real property. This creates more opportunities for school districts in the same jurisdiction to be granted immunity in future cases.

Understanding case law as verdicts emerge allows faculty members and institutions to make the proper adjustments to their facilities and teaching practices. The Wells case serves as a reminder for faculty members and institutions to check and make sure the proper safety guards are in place and working. The Fontenot v. State ex rel. Department of Education (1994) case should make faculty members more aware of what types of students they are letting use dangerous machinery that requires advanced skills. Grammens v. Dollar (2010) encourages institutions or school districts to check the wording of their safety policies.

Regardless of the tools used in the classroom, sometimes what faculty members do or do not do can determine if they and/or the school is at fault. In Cureton v. Philadelphia School District (2002) although the student had his shirt untucked and voluntarily reached across the saw to turn the power on, the faculty member was at fault for allowing the student to clean the machine and not turning off the main power supply as he had done numerous times before. In Heuser ex rel. Jacobs v. Community Insurance Corporation (2009) the faculty member took no precautions to address the continual danger of the scalpels (e.g., use scissors, have the instructor perform cuts) so the school district was found liable.

As new cases are decided, faculty members and institutions need to adapt their pedagogy and policies to address the changes in the law. More recently, Western Carolina University reviewed case law and used a risk assessment model to document and gain insight into developing a safety program for their engineering technology laboratories (Ferguson et al., 2010). Using recent case law to be proactive about potential hazards may take time and money to implement, but is quicker, cheaper, and less stressful than the litigation process resulting from an accident. Dealing with a legal issue after a summons has been served is not cost effective (Janosik, 2005). Being proactive about potential litigation will save time (personal and instructional), money, and reputations (Storm, 1993).

Case law pertaining to negligence resulting in injury of students in higher education environments is limited; however, the courts have established precedence in areas that offer insight for faculty members and administrators to develop laboratory safety guidelines and procedures (Ferguson et al., 2010). As new cases emerge, faculty members, administrators, and institutions should pay attention to the outcome of the cases. New rulings in tort liability cases may open up doors to increased liability for faculty members and institutions. College administrators need to be alert for important changes in the law. Focusing only on case law and emerging issues is only one portion of the education enterprise, which provides a limited view of legal issues that may be developing (Janosik, 2005). Most important, legal cases should serve as a learning tool for STEM educators. Faculty members and institutions cannot predict or prevent every accident, but they can implement proper systems to try to avoid being held liable if a similar incident happens at their institution.

TORT LIABILITY

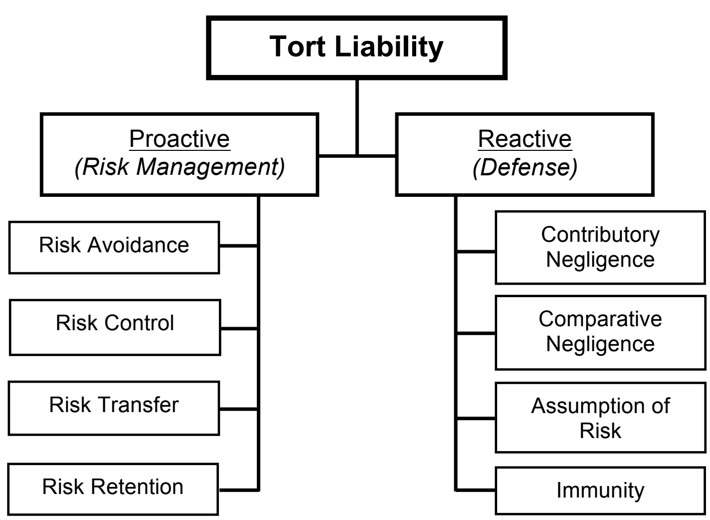
Best Practices to Avoid Tort Liability

According to Kaplan and Lee (2007) risk management can help stabilize the institution's financial condition over time and improve the morale and performance of faculty by alleviating their concerns about personal liability. Kaplin and Lee (2007) suggested four major methods of risk management to avoid legal liability: (a) risk avoidance, (b) risk control, (c) risk transfer, and (d) risk retention (Figure 2). Risk avoidance is the best method to reduce liability because the activity is avoided or eliminated due to foreseeable liability concerns (Toglia, 2009). Sometimes a risk cannot be avoided; therefore, other methods such as risk control can be implemented. Risk control is when restrictions are created to reduce the frequency or severity of exposure to liability.

Risk transfer could involve methods such as purchasing liability insurance and the use of waivers (Kaplan & Lee, 2007). Unfortunately institution and union insurances may not be enough, and sometimes these exclude hazardous activities undertaken by STEM education employees. An individual liability insurance policy, such as the one offered through the ITEEA is added protection in the event that litigation is brought against an individual. Another option is for STEM education employees to purchase a "business pursuits" endorsement or attach a rider to their homeowners insurance, which acts as professional liability coverage (Toglia, 2009). Individual liability insurance policies are usually fairly inexpensive, especially if they are ever needed to cover legal fees associated with a lawsuit. Institutions and faculty members should check with their school to ensure what type of liability insurance they have and what it covers prior to the event of an accident. Risk transfer could also involve hiring a private company to maintain the equipment in a laboratory. However, transfer of risk is not a universal defense for all institutions facing litigation (Toglia, 2009).

The last method to avoid liability is risk retention because the insurance cost is too high, the expected losses are minimal, or the probability of risk is extremely small. Institutions and employees must decide the probability and cost of a potential lawsuit before they approve the activity and take any precautions. In the event that a lawsuit is brought against an institution or employee, there are certain defenses that can prevent them from being found liable.

Figure 2. Addressing Tort Liability in STEM Education



Defenses Against Tort Liability

The four defenses against tort lawsuits are (a) contributory negligence, (b) comparative negligence, (c) assumption of risk, and (d) immunity (Figure 2). Contributory negligence results when the student's own negligent action contributed to his or her injury. Most experts believe this defense is of little value when a minor is involved (Toglia, 2009). Comparative negligence allows juries to find the degree to which each party is negligent, authorizing recovery based on the degree of fault (Gathercoal & Stern, 1987). For example, a court can determine what percentage the defendant was liable and ask that person to pay for a percentage of the damages. Assumption of risk is when a participant engages in an activity that involves a risk and is deemed to have assumed the risks inherent in the activity (Hall & Marsh, 2003). The assumption of risk is dependent upon the age, maturity, experience, and familiarity with the risk, despite any signed waiver. Assumption of risk is usually not a viable defense in a negligence claim if an employee fell below the standard of care (Gathercoal & Stern, 1987).

The last defense is immunity, which was previously discussed. It is important to note that immunity varies from state to state (Kaplin & Lee, 2007), therefore employees and institutions must know immunity laws specific to their state. Despite the defenses described previously, employees should always act within their job description and good faith to avoid being liable for an accident. The best defense against a tort is anticipating legal issues by reviewing case law and keeping current on any changes in the law (Janosik, 2005).

FUTURE IMPLICATIONS

Presenting recent case law to pre-service teachers, in-service teachers, and other employees may be a challenge. Simply passing along the information may not assure that the appropriate attention and reflection is given to the cases. Using a case study pedagogical approach can provide employees the chance to put their selves in the classroom situation, discuss the outcomes, and identify things they would have done differently before the final verdict is revealed. This case study pedagogical approach is often implemented in medicine and law schools. In law, new decisions, new cases, and new laws are built upon old decisions (Herreid, 1997). Harvard Law School (2012) uses a case study approach to educate their students. They found that the case study teaching method engages readers in active learning by putting them in the shoes of real people solving real problems. They also found that it is an appropriate teaching method for undergraduate and graduate education, as well as professional development workshops and courses. It elicits dynamic interaction in a real problem-solving scenario.

Most articles have been written recommending safe practices for science and TED faculty members to avoid liability in the event of an accident. Gunter (2007), Haynie (2009), DeLuca & Haynie (2007), Roy (2009), and Toglia (2009) all provide an extensive list of recommendations to create a safe learning environment in the laboratory. The number one recommendation that Haynie (2009) stressed is to have all persons wear safety glasses in the laboratory at all times. Togolia (2009) emphasized implementing safety throughout the curriculum and modeling safe practices, which is also mirrored in Haynie's article stating that safety is a process that is continually reinforced, not an event. Roy (2009) described safety actions for students and safety actions for teachers. He stressed the importance of lab safety training, a student and parent lab safety acknowledgment form, safety tests, MSDS sheets, keeping record of safety lesson plans, keeping record of student attendance during safety lessons, putting safety issues on department meeting agendas, displaying safety signs around the lab, and recording equipment inspections. All of these strategies, if recorded properly, create a paper trail that could be used in a court of law to prove the faculty member and school took numerous precautions to promote a safe learning environment. These articles should be referenced for professional development and safety training of pre-service and in-service teachers.

Ferguson et al. (2010) provided a set of safety recommendations for higher education faculty slightly different than Gunter (2007), Haynie (2009), DeLuca & Haynie (2007), Roy (2011), and Toglia's (2009) recommendations geared toward P-12 teachers. Among the many recommendations, Ferguson et al. (2010)

recommended working with the institution's attorneys to establish a safety plan and conduct workshops to learn the law. Another recommendation they make is to never accept an assignment teaching in a laboratory in which one is not professionally prepared to teach. With the shortage of qualified STEM teachers to fill positions, this recommendation may be one that is often breached. Despite the differences in P-12 and higher education, all of the articles provide valid recommendations that should be followed at all levels. Although employees and institutions cannot prevent being sued, they can take the proper precautions to prove that they did everything they could to avoid foreseeable danger.

CONCLUSION

Since institutions and faculty members cannot predict when they will be sued, it is critical to stay current on developing issues via case law. Bridging the gap between P-12 and higher education is essential to planning for potential legal issues coming down the pipeline (Janosik, 2005). Safety and liability will continue to be an issue for STEM educators. The hands-on design-based learning nature of these courses will carry increased liability compared to many other content areas. This design-based learning methodology that defines STEM education must remain the crux of its pedagogical practices.

Keeping a hands-on design-based learning pedagogy will require STEM education teacher preparation faculty to better prepare pre-service teachers and enhance in-service teachers' knowledge of safety and liability. Instructing pre-service and in-service STEM educators and administrators how to follow developing case law can save time, money, and injuries that result from accidents (Janosik, 2005). STEM educators of all disciplines must be adequately trained to safely implement the types of curriculums that national organizations and councils are requiring STEM educators to use. Safety training has been an essential part of the technology education curriculum for years. TED education must share its expertise in this area with the other STEM education disciplines to assure collaboration among educators who can safely deliver an authentic context for problem solving and transfer of knowledge that makes STEM education unique (Wells, 2010).

STEM educators cannot fear liability and sacrifice the advantages of laboratory experiences that foster inquiry-based science and are essential to student learning (Zirkel & Barnes, 2011). As Ferguson et al. (2010) suggested, "Tort law is changing constantly; it would be wise for professors to stay abreast of the law by periodically reading law review articles in scholarly journals" (p. 8). Through proper preparation and professional development, faculty and institutions can use case law to stay informed of the newest litigation and adapt their practices accordingly. Modern technology is constantly developing improved devices (Storm, 1993) with new safety considerations to learn. Without losing the laboratory learning experiences integral to STEM education, teachers in these fields must adapt to meet the safety requirements of future technologies and train professionals to keep student safety the center of focus.

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References

American Association for the Advancement of Science (AAAS). (1989). *Science for all Americans*. Washington, DC: Author.

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for science literacy: Project 2061*. Washington, DC: Author.

American Association for the Advancement of Science (AAAS). (2011). *Science for all Americans* Retrieved from http://www.project2061.org/publications/sfaa/online/sfaatoc.htm

Asunda, P. A. (2011). Open courseware and STEM initiatives in career and technical education. *Journal of sTEm Teacher Education*, *48*(2), 6-37.

Barrios, L. C., Jones, S. E., & Gallagher, S. S. (2007). Legal liability: The consequences of school injury. *Journal of School Health*, *77*(5), 273-279. doi: 10.1111/j.1746-1561.2007.00203.x

Batten, D. (2010). Strict Liability. *In Gale encyclopedia of American law* (3rd ed.) (Vol. 9, pp. 403-404). Detroit, MI: Gale.

Bergeson, T., Heuschel, M. A., Lahmann, M., Fieldman, R., Broom, M., Opp, M., Stanford, R., & Olsen, J. (2002). *Safety guide for career and technical education*. Retrieved from the Centers for Disease Control, National Institute for Occupational Safety and Health website: http://www.cdc gov/niosh/docs/2004-101/pdfs/Safe.pdf

Cureton v. Philadelphia School District, 798 A.2d 279 (Pa. Commw. Ct. 2002).

DeLuca, V. W., & Haynie, W. J. (2007). Safety system design for technology education (3rd ed.). Reston, VA: ITEA.

Ferguson, C., Ford, G., & Bumgarner, R. (2010, April). A discussion of tort liability in engineering technology laboratories. *The Engineering Educator of 2016*. Symposium conducted at the meeting of the American Society for Engineering Education Southeast Section Conference, Blacksburg, VA.

Fontenot v. State ex rel. Department of Education, 635 So. 2d 627 (La. App. 1994).

Frantz, N. R., Jr., Friedenberg, J. E., Gregson, J. A., & Walter, R. A. (1996). Standards of quality for the preparation and certification of trade and industrial (T&I) education teachers. *Journal of Industrial Teacher Education*, *34*(1), 31-40.

Gathercoal, F., & Stern, S. (1987). *Legal issues for industrial educators*. Ann Arbor, MI: Prakken Publications.

Grammens v. Dollar, 287 Ga. 618 (Ga. 2010).

Gunter, R. E. (2007). Checking safety in technology education. *Technology Teacher*, *66*(6), 5-13.

Hall, B. H., & Marsh, R. J. (2003). *Legal issues in career and technical education*. Homewood, IL: American Technical Publishers.

Harvard Law School. (2012). *The case study teaching method*. Retrieved from http://casestudies.law harvard.edu/the-case-study-teaching-method/

Haynie, W. J., III. (2008). Are we compromising safety in the preparation of technology education teachers? *Journal of Technology Education*, *19*(2), 94-98.

Haynie, W. J., III. (2009). Safety and liability in the new technology laboratory. *Technology Teacher*, *69*(3), 31-36.

Herreid, C. F. (1997). What is a case? *Journal of College Science Teaching*, *27*(2), 92-94.

Herschbach, D. R. (2011). The STEM initiative: Constraints and challenges. *Journal of sTEm Teacher Education*. *48*(1), 96-122.

Heuser ex rel. Jacobs v. Community Insurance Corporation, 321 Wis. 2d 729. (Wis. App 2009).

International Technology Education Association (ITEA/ITEEA). (2000/2002/2007). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

Janosik, S. M. (2005). Anticipating legal issues in higher education. *NASPA Journal*, *42*(4), 401-414.

Kaplin, W. A., & Lee, B. A. (2007). *The law of higher education: Student Version* (4th ed.). San Francisco, CA: Jossey-Bass.

Kigin, D. J. (1983). *Teacher liability in school shop accidents*. Ann Arbor, MI: Prakken Publications.

LoFurno v. Garnet Valley School District, 904 A.2d 980 (Pa. Commw. Ct. 2006).

National Commission of Excellence in Education (NCEE). (1983). *A nation at risk: The imperative for educational reform*. Washington, DC: Author.

National Research Council (NRC). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

Niles v. Board of Regents, 222 Ga. App. 59 (Ga. App. 1996).

Ochoa, T. A. (2007). Case #16 A special case of diversity: Students with disabilities in higher education. In O. G. Brown, K. G. Hinton, & M. Howard-Hamilton (Eds.), *Unleashing suppressed voices on college campuses: Diversity issues in higher education* (Vol. 19, pp. 193-198). New York: Peter Lang.

Owen, D. G. (2007). The five elements of negligence. Hofstra Law Review, *35*(4), 1671.

Phillips, J. J. (1986). Comments on the report of the governor's commission on tort and liability insurance reform. *Tennessee Law Review*, *53*, 679-799.

Pennsylvania Department of Education (PDE). (2012). *Safety guidelines for technology education and elementary science/technology education*. Bureau of Curriculum and Academic Services: Division of Curriculum and Instruction. Retrieved from http://www.portal.state.pa.us portal/server.pt?open=18&objID=356367&mode=2

Pennsylvania Judicial Code, 42 Pa. C.S.A. § 8541 (1980).

Pennsylvania Judicial Code, 42 Pa. C.S.A. § 8542 (1980).

Reed Elsevier Inc. (2013). LexisNexis Academic. Retrieved from http://www.lexisnexis.com/hottopics lnacademic/

Roy, K. (2009). The safety legal paper trail. *Science Teacher*, *76*(2), 12-13.

Roy, K. (2011). Lab safety – A shared responsibility. *Science Teacher*, *78*(9), 8.

Roy, K. (2012). STEM: A question of safety. *Science Scope*, *36*(1), 84-85.

Sanders, M. (2012, December). *Integrative STEM education as "best practice."* Paper presented at the Seventh Biennial International Technology Education Research Conference, Queensland, Australia. Retrieved from www.sp2.upenn.edu/ostrc/stem/documents/IntegrativeSTEM.pdf

Schimmel, D., Fischer, L., & Stellman, L. R. (2008). School law: *What every educator should know*. Boston, MA: Pearson.

Storm, G. (1993). *Managing the occupational education laboratory* (2nd ed.). Ann Arbor, MI: Prakken Publications.

Thomson Reuters. (2013a). FindLaw. Retrieved from http://lp.findlaw.com/

Thomson Reuters. (2013b). Westlaw Classic. Retrieved from http://web2.westlaw.com

Toglia, T. V. (2009). Keeping it safe: Safety and liability advice for CTE programs. *Tech Directions*, *68*(6), 17-21.

Usher v. Upper Saint Clair School District, 487 A.2d 1022 (Pa. Commw. Ct. 1985).

Utah Department of Health. (2007). *Utah student injury report data, school years 2001-02 to 2005-06, grades 7-12*. Violence and Injury Prevention Program. Retrieved from http://utah.ptfs.com/awweb guest.jsp?smd=1&cl=all_lib&lb_document_id=11835

Wells, J. G. (2008, November). *STEM education: the potential of technology education*. Paper presented at the 95th Mississippi Valley Technology Teacher Education Conference, St. Louis, MO.

Wells, J. G. (2010). Research on teaching and learning in science education: Potentials in technology education. In P. Reed & J. LaPorte (Eds.), *Research in technology education: Council on technology teacher education*, 59th yearbook (pp. 192-217). Reston, VA: ITEEA.

Wells, J. G., & Ernst, J. V. (2012). Integrative STEM education. *Virginia Tech School of Education*. Retrieved from http://www.soe.vt.edu/istemed/

Wells v. Harrisburg Area School District, 884 A.2d 946 (Pa. Commw. Ct. 2005).

Zirkel, P. A., & Barnes, M. B. (2011). Negligence liability of K-12 chemistry teachers: The need for legal balance and responsible action. *Journal of Chemical Education*, *88*(8), 1050.

[1]*Disclaimer: This article is not intended to replace advice from competent legal counsel. It merely presents cases that recently occurred in STEM education classrooms and shows how institutions and individuals can be proactive in avoiding liability.*

A Review of the Impact of ISO 9000 and ISO 14000 Certifications

By Eli Kofi Aba and M. Affan Badar

Abstract

This paper presents some of the most important findings of studies of the impact of ISO 9000 and ISO 14000 certifications on organizations, based on a literature review. The article discusses potential synergistic advantages that can be derived from an integrated quality-environment system and qualitative benefits using ISO 9000 and 14000 certifications. This article also discusses some of the limitations of the current literature and how these can be addressed in the future research.

Keywords: ISO 9000, ISO 14000, quality systems, environmental systems

Introduction

Global competitiveness, an attribute of today's economic scenario, has compelled companies to invest more and more resources into enhancing their management efficiency. This economic and market globalization has given rise to an increasingly important role of standards. Guasch, Racine, Sánchez, and Diop (2007) and the National Research Council (NRC) (1995) explained the positive economic effects of standards: ability to exploit network externalities, increase productive and innovative efficiency, decrease imperfect information, diffuse information, reduce cost, promote competition, increase compatibility, promote process management, and foster public welfare. These benefits are not mutually exclusive (NRC, 1995). Guasch et al. (2007) stated the contradictory negative economic effects of standards: imposition of constraints on innovation and the decrease of market competition. However, Guasch et al. (2007) concluded that the positive effects of standards outweighed the negative effects.

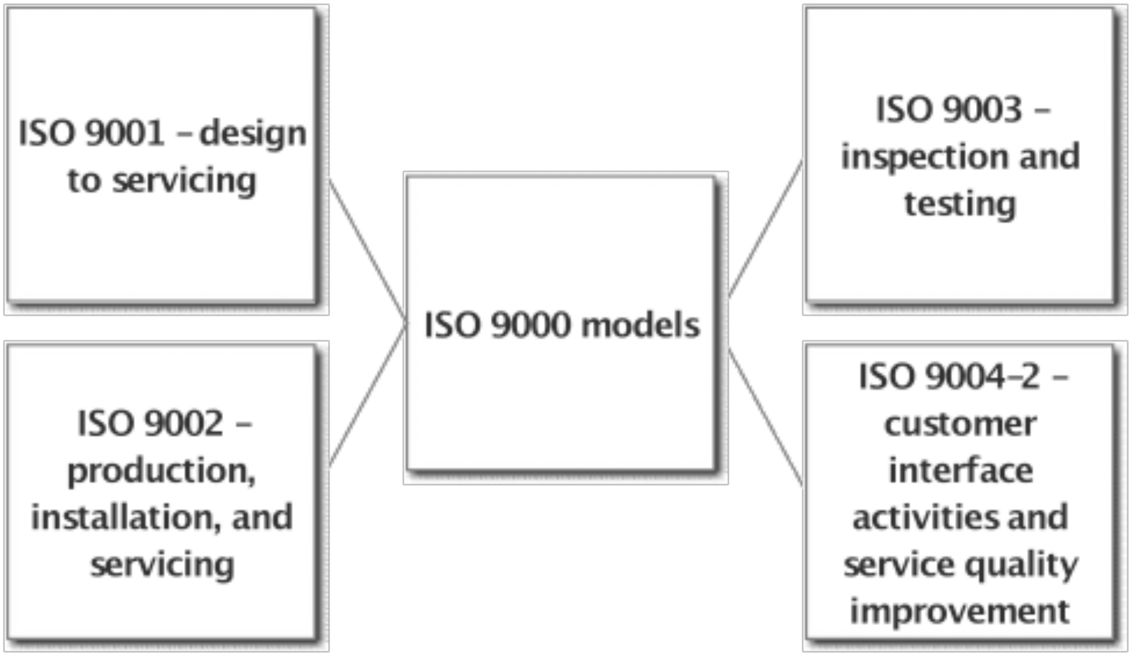
Approximately 60 programs and awards reward firms for improving quality globally (Wilson, Walsh, & Needy, 2003). The most famous ones are the Malcolm Baldrige National Quality Award, Six Sigma, ISO 14000 programs, and ISO 9000 programs (Troy, 1992). Most employers in the United States would want to know if the financial advantages associated with ISO 9000 and ISO 14000 registrations outweigh the costs associated with obtaining these certifications. ISO 9000 and ISO 14000 are not standards in themselves; they are descriptors for series of standards as described in the next sections. The main standards are ISO 9001 and ISO 14001, which set out the requirements for achieving efficient quality management and environmental management systems, respectively (Morris, 2004). In this article, ISO 9000 and ISO 14000 refer interchangeably to ISO 9001 and ISO 14001, respectively.

ISO 9000

The International Organization of Standardization (ISO) was formed in Geneva, Switzerland, in 1946 to develop international, industrial, and quality standards as a model for quality assurance standards in design, development, production, installation, and service. ISO 9000 is a series of quality management standards published by the ISO in 1987 after a process of consensus handled by ISO Technical Committee 176; these are codified, verifiable, and easily adaptable (Wilson et al., 2003). ISO 9000 standards are so adaptable that updates and changes have been made roughly every three years since their adoption. According to Pantouvakis and Dimas (2010), ISO 9000 helps companies establish quality assurance systems. Kartha (2004) stressed that these standards are generic and not only limited to products or services, but they also apply to all processes and can be employed by manufacturing and service organizations.

Figure 1 shows the four ISO 9000 models for quality systems. The ISO 9001 model depicts all activities from researching, designing, building, shipping, installing, and servicing. The ISO 9002 model guarantees production, installation, and servicing. The ISO 9003 model is restricted to inspection and testing. The ISO 9004 or 9004-2 model deals with customer interface activities and service quality improvement (Todorov, 1996).

Figure 1. The Four Models for Quality Management System (Todorov, 1996)



ISO 9000 helps firms with internal improvements and strategic benefits that accompany the quality tool. Wilson et al. (2003) pointed out that the internal improvements comprise all business activities that are associated with a product and should be carried out in a three-part continuous cycle of planning, control, and documentation. ISO (2011) states a company that obtains ISO 9000 fulfills a customer's quality requirements and applicable regulatory requirements, while targeting enhanced customer satisfaction and achievement of continual improvement of its performance.

ISO 14000

ISO 14000 is a descriptor for a series of environmental management standards that was developed based on the success of the international quality standard ISO 9000 and in response to the global concern about the environment (Delmas & Montiel, 2008; Morris, 2004). According to Sayre (1996), ISO 14000 is derived somewhat from British Standard 7750, which includes the specification for environmental management systems and is considered globally a foundation for sound environmental performance. Furthermore, the 1994 American National Standard, ANSI/ASQC E4 might enhance the understanding of the components of ISO 14000. ISO (2011) pointed out that a company that obtains ISO 14000 certification minimizes the harmful effects that occur from its activities to the environment and accomplishes continual improvement of its environmental performance.

ISO 9000 and ISO 14000 are similar in their processes, but they target different elements of a company (quality versus the environmental impact of operations). Delmas and Montiel (2008) showed that ISO 14000, to some extent, complements the quality management system by establishing a similar system for the management of the environmental impact; however, these standards also address slightly different audiences. ISO 9000 aims to improve quality and facilitate business objectives. ISO 14000 targets the improvement of environmental performance and the facilitation of relationships with not only market actors, but also nonmarket actors, such as regulatory agencies and nongovernmental organizations (NGOs). The success of the implementation of ISO 9000 promotes the adoption of ISO 14000.

Impact of ISO 9000

McAdam and McKeown (1999) mentioned that the main benefit of ISO 9000 is that it gives rise to an effective quality system that assists in the elimination of errors, which eventually saves money on rework and scrap. They also claimed that ISO 9000 offers marketing benefits because ISO 9000 certification indicates an internationally recognized level of quality. According to Lloyd's Register Quality Assurance Ltd. (LRQA, 1995), the following reasons are why companies implement ISO 9000: pressure from large customers; reduce first time failure; reduce the costs of customer claims; get things right the first time; improve service to the customers and increase competitiveness; and maintain contracts with existing customers. Chow-Chua, Goh, and Boon Wan (2003) indicated that the two most common benefits of the ISO 9000 certification are increase in productivity and access to overseas markets.

Most companies place great emphasis on ISO certifications as a marketing tool. Burgess (1993) highlighted that certification tends to lead to improved marketing. However, Burgess also explained that most companies, irrespective of location, see improved efficiency as a major benefit. Porter and Rayner (1991) also made the same conclusions, that benefits from certification are associated with marketing factors. Additionally, Porter and Rayner (1991) mentioned the correlation between the benefits companies derive from certification and the reasons for their pursuing certification. Other studies indicate that benefits of ISO 9000 can far outweigh the costs of registering, but ISO 9000 should not be seen as a "quick fix, but as a long-term investment which requires commitment and continued effort" (McAdam & McKeown, 1999, p. 232).

Quinn (1992) stressed that considerable effort is made both in terms of money and valuable management resources to reach the level necessary for the achievement of ISO 9000 quality standards. However, Quinn stated that quality rewards itself many times over "in repeat orders from satisfied customers, in new customers . . . reduced waste . . . and in greater employee job satisfaction" (McAdam & McKeown, 1999, p. 232).

ISO 9000-associated papers focus mainly on the qualitative benefits associated with certification, such as increases in communication and an understanding of how the firm works. Regarding the quantitative benefits, there is little published documentation. Corbett, Montes, Kirsch, and Alvarez-Gil (2002) quantitatively showed that ISO certification does result in improved financial performance against competitors. Porter and Rayner (1991) found that the cost of obtaining ISO 9000 can usually be recovered within three years through reductions in quality costs. However, Corbett et al. (2002) indicated that certification does not lead to significant internal financial improvements. Wilson et al. (2003) concluded that the economic success reported by companies after obtaining ISO 9000 certification may be exaggerated, because this success cannot be guaranteed. Witcher (1994) claimed ISO 9000 helps with the promotion of the accountability of the processes but does not impact all the business activities that indicate the capability of the organization to satisfy customer requirements. Taylor (1995) mentioned that most companies lack measurement of the financial impact of ISO 9000 and Chow-Chua et al. (2003) pointed out that very few studies actually measure financial performance.

Several studies (Corbett, Montes-Sancho, & Kirsch, 2005; Easton & Jarrell, 1998; Hendricks, & Singhal, 1997) showed an improvement in the financial results of certified companies, while some researchers (Powell, 1995; Samson & Terziovski, 1999; Staw & Epstein 2000; Terziovski, Samson, & Dow, 1997) did not find better business performance after certification. Other researchers (Feng, Terzioski, & Samson, 2008; Heras, Casadesus, & Dick, 2002; Martinez-Costa & Martinez-Lorente, 2008) indicated the negative effect that ISO 9000 certification had on company benefits and profits. Casadesus and Gimenez (2000) mentioned customers' low levels of satisfaction with the implementation of the standards. It should be noted that the above studies collected evidence over a short period of time (three years) after the company obtained certification. Martinez-Costa and Martinez-Lorente's (2008) findings indicated companies obtained considerably less earnings and returns on assets (ROAs) during the three years after obtaining registration. From these findings, these authors also emphasized that the short-term results for a company's financial performance are not as impressive as the long-term results. These companies also had a noticeable increase in operational costs over the same period, but sales and personnel expenses were intact.

Overall, according to McAdam and McKeown (1999), the impact of ISO 9000 has been very positive—over 50% (or four times as many companies) believed it saves money rather than costs money, although small ISO-certified companies are less likely to state that ISO 9000 saves money and 75% of the service sector said that ISO 9000 costs money. Quazi and Padibjo (1998) stated that certified companies saw an improvement in their quality and an increase in their sales and market share. Haversjo (2000) indicated that an increase in sales correlates with an increase in the rate of return for certified companies, as opposed to noncertified companies. On a review of the financial and scale efficiency of 18 European port authorities, some certified and some not, Pantouvakis and Dimas (2010) revealed that ISO certified ports are financially more efficient than their noncertified competitors.

Impact of ISO 14000

According to Sayre (1996), ISO 14000 advocates "sustainable development for each and every nation and sustainable development for each and every person" (p. 1). This means a firm that is committed to ISO 14000 ensures activities, products, and services are good for humans and the world. Moreover, ISO 14000 fosters principles and practices that are germane to the competitive advantage of sound environmental performance: resource allocation, responsibility and accountability, and continuous performance evaluation for improvement.

The implementation of effective ISO 14000 standards by a firm can offer these benefits: protecting human health and the environment from the potential impacts of its activities, products, and services; helping with the maintenance and improvement of the quality of the environment; meeting customers' environmental expectations; maintaining good public and community relations; satisfying investor criteria and improving access to capital; providing insurance at a reasonable cost; gaining an enhanced image and market share; fulfilling vendor certification criteria; improving cost control; limiting liabilities; providing resource conservation; supplying effective technology development and transfer; and giving confidence to interested parties and shareholders that policies, objectives, and targets are conformed to: stress is on prevention first, then regular occurrence of reasonable care and regulatory compliance, and finally, a system design that includes continual improvement (Sayre, 1996). According to Johnson (1997), ISO 14000 builds a single global management system that allows for effective management of environmental responsibilities. It also reduces liability, controls costs, documents a firm's commitment to government, and finally fosters a firm's concern for the public. ISO 14000 has the potential to lead to competitive advantages for businesses in areas such as enhancing raw material and strengthening supply management, in order to justify and make the administration of legally binding environmental laws safer, as well as to improve corporate image (Renzi & Cappelli, 2000).

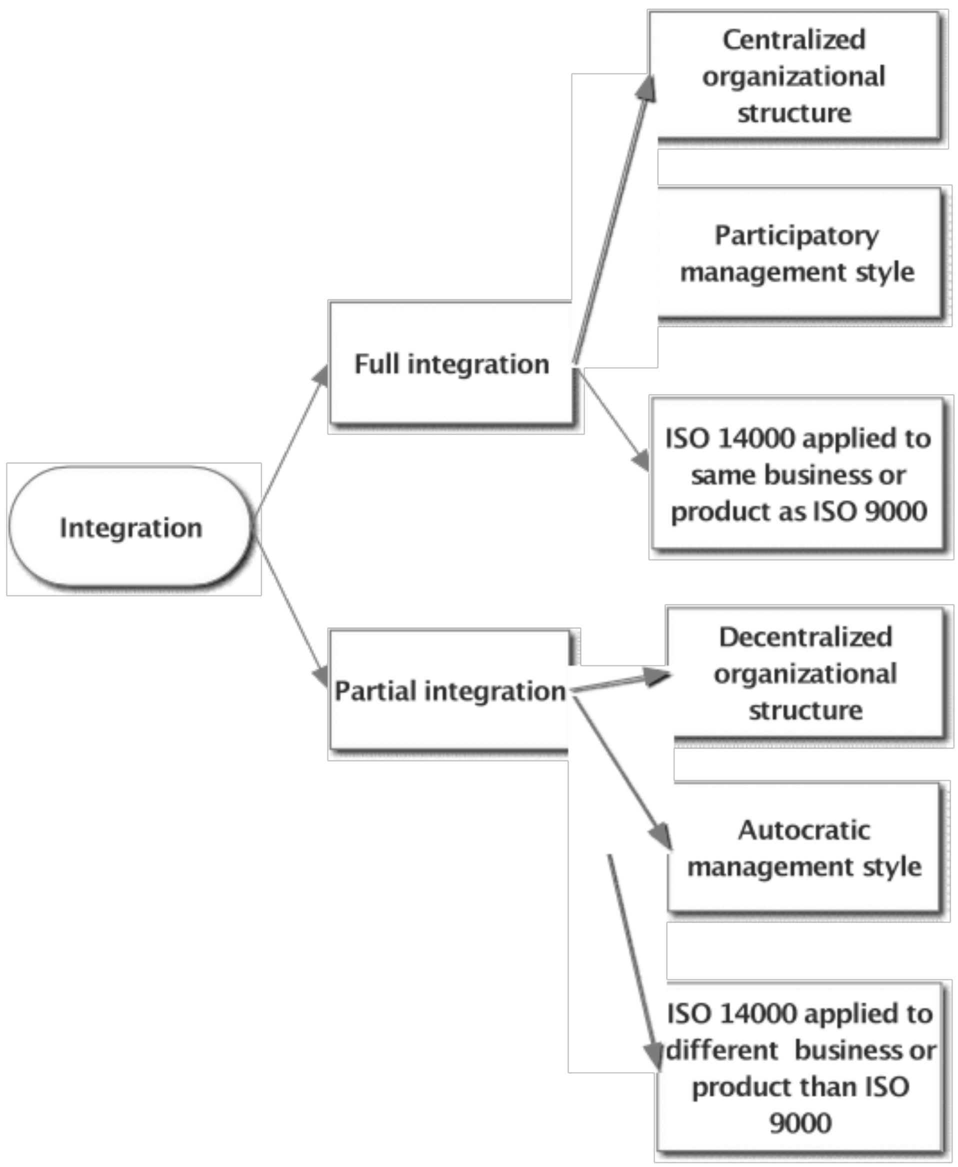
Integration of ISO 9000 and ISO 14000

The formation of one cohesive management system comes from two stand-alone systems: quality management systems (ISO 9000) and environmental management systems (ISO 14000). The integration of ISO 9000 and ISO 14000 is dependent on two assumptions. First, firms integrating the two stand-alone systems must have in place a mature quality management system and will employ ISO 14000 to expand it. Second, the quality management system in place conforms to ISO 9001, ISO 9002, or QS-9000 (Block & Marash, 1999). There are two ways of integrating ISO 9000 and ISO 14000. First, full integration leads to a single system that accommodates all of the requirements imposed by ISO 14000 and ISO 9000. The advantage this brings is one system manual in addition to one set of procedures, one audit that looks at the combined requirements, and one management review (Block & Marash, 1999). Second, partial integration involves keeping separate ISO 9000 and ISO 14000 internal audit processes, registration audits, and surveillance audits. By doing this, two system manuals are created: one for ISO 9000 and one for ISO 14000. Under the appropriate circumstances, an ISO 14000 system employs procedures from the ISO 9000 system. Such procedures may be modified to conform to ISO 14000 requirements; however, this must be done to ensure that the ISO 9000 system is not compromised. A noteworthy outcome of the partial integration is two sets of documentation, much of which may be unnecessary (Block & Marash, 1999).

Figure 2 displays the factors that influence either full integration or partial integration. Three factors that are parts of the corporate culture to consider are organizational structure, management style, and scope of system. These factors help in making the decision either to fully or partially integrate ISO 9000 and ISO 14000.

Integration of quality management and environmental management systems is advantageous in many ways. First, it brings together quality assurance and the environmental staff. This helps the staff to know more about each system. For example, the integration helps the quality management staff to be more knowledgeable about their firm's environmental impacts and legal obligations, while those of the quality environmental staff would be aware of established procedures associated to document control, records, and similar activities. Some researchers (Corbett & Cutler, 2000; Gupta

Figure 2. Flow Chart of Factors Impacting Full Versus Partial Integration (Block & Marash, 1999)



& Sharma, 1996; Kitazawa & Sarkis, 2000; Klassen, 2000) have argued that environmental managers should be integrated with quality managers in companies so they can take advantage of their possible synergies.

According to Block and Marash (1999), advantages of stand-alone ISO 9000 standards are twofold. First, these standards offer both a framework for firms that want to implement effective quality management systems and requirements against which companies can evaluate the quality management systems of their suppliers. Second, suppliers employed these standards to fulfill quality management requirements imposed by their customers. Stand-alone ISO 14000 improves a firm's environmental performance through prevention of pollution problems. Other related benefits include cost savings and improved relations with state environmental agencies (Block & Marash, 1999).

Integration of ISO 14000 into an existing ISO 9000 has significant advantages. First, the employment of existing ISO 9000 procedures to fulfill ISO 14000 requirements ensures consistency and eliminates redundancy because both standards require almost the same number of procedures. Second, using existing ISO 9000 procedures also helps to create significant cost savings in developing and implementing ISO 14000 (Block & Marash, 1999). Third, introducing ISO 14000 is seen as a normal way of doing business, so that ISO 14000 is no longer seen as the primary responsibility of the environmental department. Operationally, a fully integrated system produces an umbrella of programs that accommodates all facets of business, ranging from product quality and customer service to maintaining operations in a safe and environmentally acceptable way. Renzi and Cappelli (2000) pointed out that the following advantages are derived from integrated quality-environment system: "cost reduction, because it improves data and personnel management; homogeneity in management methodologies; and a decrease in the bulk of company papers and the creation of common forms that can be more easily used by several operators" (p. 2).

Limitations of the Current Literature

In the literature reviewed for this article, authors have discussed the advantages of both ISO 9000 and ISO 14000. However, these studies are limited to qualitative research that occurred during a short time frame.

Arbuckle's (2004) results showed a statistically significant change in total assets and return on assets for a period of two years after selected companies were certified in ISO 9000. However, Arbuckle's control groups were limited, because the researcher did not compare with non-ISO-certified companies to determine if the changes in total assets or return on assets were the result of only ISO certifications or other political and economic factors. Based on Martinez-Costa and Martinez-Lorente's (2008) findings, short-term results for a company's financial performance are not as impressive as the long-term ones; therefore, these findings imply that a longer time frame is needed to prove that Arbuckle's results would hold. However, Wayhan, Kirche, and Khumawala (2002) indicated that ISO 9000 certification has a very limited impact on financial performance, as measured by return on assets; however, this effect dissipates quickly over time. Renzi and Cappelli (2000) pointed out the advantages, which are derived from an integrated quality-environment system, make a company very competitive. There is a need for more quantitative research with a longer time frame on the financial benefits of the integration of ISO 9000 and ISO 14000.

Conclusion

ISO 9000 and ISO 14000 programs have shown well-established net advantages that were described under their impacts in this article. Additional benefits can be derived from their integration. However, most of the current studies are limited to qualitative findings and a short time frame. Therefore, more quantitative studies with longer time frames are needed to substantiate the benefits of both stand-alone certifications and the integration of the two certifications. Also, ISO certified companies must be compared with noncertified companies to determine if the benefits in financial performance indicators are the result of only ISO certifications or other political and economic factors. In the future, the authors plan to conduct research to address these issues.

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References

Arbuckle, G. K. (2004). A comparative study of selected measures of performance of organizations before and after obtaining ISO 9000 certification as compared to the S and P 500 index. Indiana State University. ProQuest dissertations and theses, Retrieved from http://search.proquest.com/doc view/305196084?accountid=11592.

Block, M. R., & Marash, R. I. (1999). *Integrating ISO 14001 into a quality management system* Milwaukee, WI: ASQ Press.

Burgess, N. (1993). The role of consulting in quality development. *Proceedings of the World Quality Congress*, Helsinki.

Casadesus, M., & Gimenez, G. (2000). The benefits of implementation of the ISO 9000 standard: Empirical research in 288 Spanish companies. *The TQM Magazine*, 12(6), 432-441.

Chow-Chua, C., Goh, M., & Boon Wan, T. (2003). Does ISO 9000 certification improve business performance? *International Journal of Quality and Reliability Management*, 20(8), 936-953.

Corbett, C. J., Montes, M. J., Kirsch, D. A., & Alvarez-Gil, M. J. (2002). Does ISO 9000 certification pay? *ISO Management Systems*, 2(4), 31-40.

Corbett, C., Montes-Sancho, M., & Kirsch, D. (2005). The financial impact of ISO 9000 certification in the United States: An empirical analysis. *Management Science*, 51, 1046-1059.

Corbett, L., & Cutler, D. (2000). Environmental management systems in the New Zealand plastics industry. *International Journal of Operations and Production Management*, 20, 204-224.

Delmas, M., & Montiel, I. (2008). The diffusion of voluntary international management standards: Responsible care, ISO 9000, and ISO 14001 in the chemical industry. *Policy Studies Journal*, 36(1), 65-93. Retrieved from EBSCOhost.

Easton, G. S., & Jarrell, S. L. (1998). The effects of total quality management on corporate performance: An empirical investigation. Journal of Business, 71, 253-307.

Feng, M., Terzioski, M., & Samson, D. (2008). Relationship of ISO 9001:2000 quality system certification with operational and business performance: A survey in Australia and New Zealand-based manufacturing and service companies. *Journal of Manufacturing Technology Management*, 19(1), 22-37.

Guasch, J. L., Racine, J. L., Sanchez, I., & Diop, M. (2007). *Quality systems and standards for a competitive edge*. Washington, DC: World Bank Publications.

Gupta, M., & Sharma, K. (1996). Environmental operations management: An opportunity for improvement. *Production and Inventory Management Journal*, 37, 40- 46.

Haversjo, T. (2000). The financial effects of ISO 9000 registration for Danish companies. *Managerial Auditing Journal*, 15(1), 47-52.

Hendricks, K., & Singhal, V. (1997). Does implementing an effective TQM program actually improve operating performance? Empirical evidence from firms that have won quality awards. *Management Science*, 43(9), 1258-1274.

Heras, I., Casadesus, M., & Dick, G. P. M. (2002). ISO 9000 certification and the bottom line: A comparative study of the profitability of Basque region companies. *Managerial Auditing Journal*, 17(1), 72-78.

ISO (2011). ISO 9000 – Quality management. Retrieved from http://www.iso.org/iso/iso_catalogue management_and_leadership_standards/quality_management.htm.

Johnson, P. (1997). ISO 14000: *The business manager's complete guide to environmental management*. New York, NY: Wiley.

Kartha, C. P. (2004). A comparison of ISO 9000:2000 quality system standards, QS 9000, ISO/TS 16949 and Baldrige criteria. *The TQM Magazine*, 16(5), 331-340.

Kitazawa, S., & Sarkis, J. (2000). The relationship between ISO 14001 and continuous source reduction programs. *International Journal of Operations and Production Management*, 20, 225-248.

Klassen, R. D. (2000). Exploring the linkage between investment in manufacturing and environmental technologies. *International Journal of Operations Management*, 20, 127-147.

Lloyd's Register Quality Assurance Ltd. (LRQA) (1995). The effects of ISO 9000 on business performance. London: LRQA Publication.

Martinez-Costa, M., & Martinez-Lorente, A. R. (2008). A triple analysis of ISO 9000 effects on company performance. *International Journal of Productivity and Performance Mangement*, 56(5/6), 484-499.

McAdam, R., & McKeown, M. (1999). Life after ISO 9000: An analysis of the impact of ISO 9000 and total quality management on small businesses in Northern Ireland. *Total Quality Management*, 10(2), 229-241. Retrieved from EBSCOhost.

Morris, A. S. (2004). *ISO 14000 environmental management standards: Engineering and financial aspects*. Hoboken, NJ: Wiley.

National Research Council (1995). *Standards, conformity assessment, and trade: Into the 21st century.* New York: National Academies Press.

Pantouvakis, A., & Dimas, A. (2010). Does ISO 9000 series certification matter for the financial performance of ports? Some preliminary findings from Europe. *Maritime Policy & Management*, 37(5), 505-522. Retrieved from EBSCOhost.

Porter, L., & Rayner, P. (1991). BS 5750/ISO 9000 – the experience of small and medium sized businesses. *International Journal of Quality and Reliability*, 18(6), 16-29.

Powell, T. C. (1995). Total quality management as competitive advantage: A review and empirical study. *Strategic Management Journal*, 16, 15-37.

Quazi, H. A., & Padibjo, S. R. (1998). A journey towards total quality management through ISO certification: A study on small and medium-sized enterprises in Singapore. I*nternational Journal of Quality and Reliability Management*, 15(5), 364-371.

Quinn, T. (1992). The role of ISO 9000 in a market led company. *Business and Finance*, 27-31.

Renzi, M. F., & Cappelli, L. L. (2000). Integration between ISO 9000 and ISO 14000: Opportunities and limits. *Total Quality Management,* 11(4/5/6), S849. Retrieved from EBSCOhost.

Samson, D. A., & Terziovski, M. (1999). The relationship between total quality management practices and operational performance. *Journal of Operations Management*, 17(5), 393-409.

Sayre, D. (1996). *Inside ISO 14000: The competitive advantage of environmental management*. Delray Beach, FL: St Lucie Press.

Staw, B., & Epstein, L. (2000). What bandwagons bring: Effects of popular management techniques on corporate performance, reputation, and CEO pay. *Administrative Science Quarterly*, 45, 523-556.

Taylor, W. (1995). Organizational differences in ISO 9000 implementation practices. *International Journal of Quality and Reliability*, 12(7), 10-38.

Terziovski, M., Samson, D. A., & Dow, D. (1997). The business value of quality management systems certification: Evidence from Australia and New Zealand. *Journal of Operations Management*, 15, 1-18.

Todorov, B. (1996). *ISO 9000 required: Your worldwide passport to customer confidence*. Portland, OR: Productivity Press.

Troy, K (Ed.). (1992). *Baldrige winners on world-class quality*. New York: The Conference Board.

Wayhan, V. B., Kirche, E. T., & Khumawala, B. M. (2002). ISO 9000 certification: The financial performance implications. *Total Quality Management*, 13(2), 217-231. Retrieved from EBSCOhost.

Wilson, J. P., Walsh, M. T., & Needy, K. L. (2003). An examination of the economic benefits of ISO 9000 and the Baldrige Award to manufacturing firms. *Engineering Management Journal*, 15(4), 3-10. Retrieved from EBSCOhost.

Witcher, B. (1994). The adoption of total quality management in Scotland. *The TQM Magazine*, 6(2), 48-53.

Reducing the Bullwhip Effect in the Supply Chain: A Study of Different Ordering Strategies

By M. Affan Badar, Shyamsundarreddy Sammidi, and Leslie Gardner

Abstract

Profitability of a company can be affected by the costs associated with backlogs and large inventories due to the bullwhip effect in the supply chain. This work aims to find an ordering strategy that is practical and can minimize the bullwhip effect. Five strategies with different levels of information about inventory and components along the supply line have been compared with the just in time (JIT) pull strategy and the usage of point of sale (POS) data. This work uses the beer game spreadsheet simulation developed by Adams, Flatto, and Gardner (2008). The simulation shows material and information flow in a four-echelon supply chain. Expressions for cost incurred and profit obtained by each player (manufacturer, distributor, wholesaler, and retailer) have been developed. Graphs for cost and profit with time are plotted. The strategy using POS data is found to be the best, and the pull strategy to be the next best. However, both require discipline. This study shows that putting information about the inventory levels and components of the supply line into an ordering strategy can also minimize the bullwhip effect.

Keywords: Supply chain, bullwhip effect, ordering strategy, beer game, inventory

Introduction

A supply chain integrates, coordinates, and controls the movement of goods and materials from a supplier to a customer to the final consumer, which therefore involves activities like buying, making, moving, and selling (Emmett, 2005). Fast- rising supply chain risks are poorly understood and managed by most companies, according to the World Economic Forum (Ladbury, 2008). Profit is the main goal of any commercial organization. To obtain profit one should reduce the costs incurred by manufacturing the product economically and reduce the supply chain costs. Supply chain costs involve inventory costs, which have a considerable share in determining the cost of the product. As the economy changes, as competition becomes more global, it is no longer company versus company, but it is supply chain versus supply chain (Henkoff, 1994).

Customer order plays a vital role in the supply chain; it actually triggers all the supply chain activities. Supply chain activities begin with a customer order and end when a satisfied customer has paid for the purchase (Chopra & Meindl, 2004). It should be noted that information flows in the supply chain are also as important as material flows. The whole supply chain process is kept moving by information flow from retailer to wholesaler, wholesaler to distributor, and distributor to manufacturer. Effective supply chain management maintains satisfied customers, growth in company market share, constant revenue growth, capability to fund continuous innovation, and capital investment for more value.

According to Simchi-Levi, Kaminsky and Simchi-Levi (2007) effective supply chain management reduces the costs incurred and thus increases the profit. It is very important to analyze demand and order in such a way that it reduces the costs incurred. Lead time is a critical component in making inventory decisions. Information delays are also one of the main components of total lead time, so electronic data interchange may reduce the delays and offer benefits through reduction in both the size and variability of orders placed (Torres & Moran, 2006).

Despite the undoubted benefits of the lean manufacturing and supply chain revolutions, supply chain instability still continues (often described as bullwhip effect), which harms firms, consumers, and the economy through excessive inventories and poor customer service (Torres & Moran, 2006). The bullwhip effect refers to the phenomenon where demand variability amplifies as one moves upstream in a supply chain, from consumption to supply points (from retailer to manufacturer) (Lee, Padmanabhan, & Whang, 1997a). It is an important demand and supply coordination problem that affects numerous organizations, and it is a major phenomenon in the beer game model (Kumar, Chandra, & Seppanen, 2007). Because of the bullwhip effect, the variability increases at each level of a supply chain as one move from customer sales to production (Chen, Drezner, Ryan, & Simchi-Levi, 2000). Lee et al. (1997a) lists demand signal processing, order batching, price fluctuations, and shortage gaming as the causes for bullwhip effect. Bhattacharya and Bandyopadhyay (2011) presented a good review of the causes of bullwhip effect. According to Chen (1999) a simple forecast formula, such as exponential smoothing or a simple moving average method can lead to bullwhip behavior in certain supply chain settings.

This work is focused toward supply chain costs by minimizing the bullwhip effect. A variety of remedies for the bullwhip effect have been proposed. For the beer game, Sterman (1989) modeled the ordering behavior of players in terms of an anchoring and adjustment heuristic. He used simulation to calculate the parameters that give the minimum total costs for the game. The beer game was developed by Sloan's System Dynamics Group in the early 1960s at MIT. It has been played all over the world by thousands of people ranging from high school students to chief executive officers and government officials (Sterman, 1992). Although this model is useful for simulation studies and development of theory, it probably has limited application for "real world" practitioners looking for effective decision rules. Industry experts and analysts have cited two recent innovations: the Internet and radio frequency identification (RFID), which t can improve supply chain performance by dampening the bull-whip effect (Lee, Padmanabhan, & Whang, 2004).

One of the most popular remedies is complete visibility of POS order data throughout the supply chain. However, Croson and Donohue (2003) conducted an experiment to evaluate whether humans actually use POS data in the beer game when such data was available. Interestingly they found that humans were still inclined to over order, although not as much as when POS data was not available. Thus, disciplined human behavior is required as well as visible information. Another potential remedy is the pull system of JIT manufacturing. Reducing variability in all aspects of a manufacturing system is one of the principles of JIT and lean manufacturing for eliminating waste and cost. JIT utilizes a pull system in which material is produced only when requested and moved to where it is needed. JIT partnerships throughout a supply chain occur when suppliers and purchasers work together to remove waste, drive down costs, and extend JIT to the supply chain (Heizer & Render, 2001). This can involve information sharing of forecasts as in point of sale (POS) strategies or can involve extending the pull system to the supply chain.

This study uses simulations developed in Microsoft Excel by Adams et al. (2008) to assess the impact of using simple adjustment heuristics based on information about inventory levels (inventory less backlog), orders in mail delays, materials in shipping delays, and the immediately upstream supplier's backlog to remedy the demand forecast updating the cause of the bullwhip effect in a four-echelon supply chain as represented by the beer game. The objective is to determine if providing all information about inventory levels and components along the supply line into an ordering strategy is superior to the JIT pull strategy and the use of POS data. Equations for cost and profit obtained by each player in the supply chain (manufacturer, distributor, wholesaler, and retailer) have been determined. The study assumes that the manufacturer satisfies the distributor's order and replenishes from limitless supply of raw material, while the distributor supplies the products to wholesaler, who in turn satisfies the demand of the retailer. The customer orders are placed with the retailer.

Background

Lee et al. (2004) mentioned that Forrester was the first person who documented the phenomenon of bullwhip effect, but the term was not coined by him. As per O'Donnell, Maguire, McIvor and Humphreys (2006), Forrester studied the dynamic behavior of simple linear supply chains and presented a practical demonstration of how various types of business policy create disturbance, and he stated that random meaningless sales fluctuations could be converted by the system into annual or seasonal production cycles.

The term "bullwhip effect" was coined by Procter & Gamble when researchers studied the demand fluctuations for Pampers. If there is no proper channel of information passage between the players in a supply chain (retailers, wholesalers, distributors and manufacturers), this leads to inefficiency like excessive inventories, quality problems, higher raw material costs, overtime expenses, and shipping costs (Lee et al. 1997a, b; Chen et al. 2000). According to Cao and Siau (1999) a change in demand is amplified as it passes between members in the supply chain.

Classic management techniques are widely employed to reduce the bullwhip effect in supply chains. In the JIT system, materials are moved when required, and the suppliers and purchasers work together to eliminate waste reducing the cost of production (Heizer & Render, 2001). Croson and Donohue (2003) examined the impact that POS data sharing had on ordering decisions in a multi-echelon supply chain. In a web-based simulation for supply chain management employing electronic data interchange similar to POS data, Machuca and Barajas (2004) found significant reductions in the bullwhip effect and supply chain inventory costs. Vendor- managed inventory (VMI) is another excellent method for reducing the bullwhip effect, and it has been employed by many international companies, such as Procter & Gamble and Wal-Mart, but the problem associated with this method is the sharing of information between retailer and factory (Lee et al. 1997a, b).

Warburton, Hodgson and Kim (2004) developed equations to compute the order and demand to nullify the bullwhip effect using a generalized order-up-to (OUT) policy. Control theory is another popular approach to reduce the bullwhip effect. Lin, Wong, Jang, Shieh, and Chu (2004) applied z-transforms to reduce the bullwhip effect, whereas Dejonckheere, Disney, Lambrecht, and Towill (2003) examined the bullwhip effect by using transfer function analysis. Many other researchers used computational intelligence techniques such as fuzzy logic, artificial neural networks, and genetic algorithms to reduce the bullwhip effect (O'Donnell et al. 2006). Carlsson and Fuller (2001) employed fuzzy logic. Goldberg (1989), Vonk, Jain, and Johnson (1997) and Moore and DeMaagd (2005) used genetic algorithms. Sarode and Khodke (2009) developed a multi-attribute decision-making technique: analytic hierarchy process (AHP).

A correct measurement is an essential start to investigating problems caused by demand amplification and to assess which measures can be taken to reduce this amplification. Fransoo and Wouters (2000) explained three issues in measuring the bullwhip effect: first, the sequence of aggregation of demand data, second filtering out the various causes of the bullwhip effect, and last the inconsistency in demand. Operational researchers also have worked on finding ways to reduce the bullwhip effect. For instance, Adelson (1966) studied simple supply chain systems, but the methodology required complex mathematics for solving the problem (Towill, Zhou, & Disney, 2007).

Simulation also has been used in supply chain management to study the bullwhip effect. The beer game is a hands-on simulation that demonstrates material and information flows in a supply chain. As mentioned previously, it was developed by the Systems Dynamic Group of Sloan school of Management at the Massachusetts Institute of Technology. Using the beer game, Sterman (1989) demonstrated that the players systematically misinterpret feedback and nonlinearities, and underestimate the delays between action and response, which leads to bad decision making and causes problems in the behavior of the supply chain (Torres & Moran, 2006). Jacobs' (2000) Internet version of the beer game is brief in description and is limited solely to its characteristics and how that game is played. Machuca and Barajas' (2004) web-based simulation using an electronic data interchange resulted in significant reductions in the bullwhip effect and supply chain inventory costs. Moyaux and McBurney (2006) used some kinds of speculators in agent-based simulations and concluded that these speculators can decrease the price fluctuations caused by the bullwhip effect. However, these speculators are not cost efficient and price bubbles may occur, particularly if too many speculators are used.

In their study, Kaminsky and Simchi-Levi (1998) showed the bullwhip effect, and they explained the effect of passing from a decentralized structure to a centralized structure and also observed the effects of shortening the lead time. Steckel, Gupta, and Banerji (2004) examined how changes in order and delivery cycles, shared POS data, and patterns of consumer demand affected the dynamics in a channel and thereby the severity of the bullwhip effect.

Cangelose and Dill (1965) considered the problem of the bullwhip effect from an organizational learning perspective. Jung, Ahn, Ahn, and Rhee (1999) analyzed the impacts of buyers' order batching had on the supplier demand correlation and capacity utilization in a simple branching supply chain involving two buyers whose demands are correlated; they found that increase in the size of the order lot mitigates the correlation of purchase orders. Cachon & Lariviere (1999) investigated the performance of balanced ordering policies in a supply chain model with multiple retailers and summarized that the bullwhip effect would depend on the order cycle and batch size. They recommended balanced ordering with small batch size and a long order interval to reduce the suppliers' demand variance.

This section has summarized a review of literature on the bullwhip effect. Researchers have employed JIT and POS data, mathematical techniques, algorithms, simulation, and balancing of order and delivery cycles in order to reduce the bullwhip effect.

The Beer Game

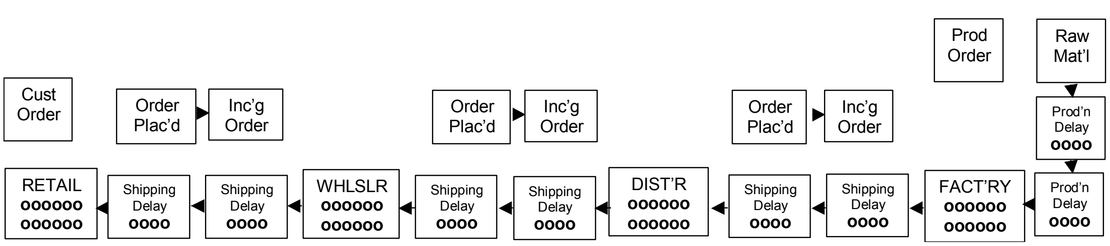
The beer game is played as a board game with four players: a retailer, a wholesaler, a distributor, and a factory (Adams et al., 2008). Customer orders are placed with the retailer who fills them to the extent possible. The retailer then orders from the wholesaler to replenish his/her stock. Similarly the wholesaler fills retailer orders and replenishes from the distributor who in turn fills wholesaler orders and replenishes from the factory. The factory fills distributor orders and replenishes from a limitless supply of raw material. All players keep records of backlogs, or unfilled orders, and attempt to fill them as soon as possible. Shipping delays of two weeks (or periods) separate each player, as do information delays of two periods. Initially, all four players have twelve units of inventory, and four units of inventory are on each square representing a shipping delay. Similarly, all of the orders in the information pipeline at the start of the game are for four units. The game board is shown in Figure 1.

The objective of the game is to fill all customer orders without carrying excessive inventories or having excessive backlogs. The players must fill backlogs eventually. For the first several periods of the game, the customer orders are at four units each period. At some point, the customer orders jump to eight units and remain at that level for the rest of the game. The only stochastic part of the beer game is the human behavior in placing orders but human behavior rarely fails to produce the bullwhip effect. The game runs for 50 periods or until the players become frustrated with excessive backlogs and inventories and the point about the bullwhip effect has been made.

Methodology

The objective of this work is to find whether using information about inventory levels and components of the supply line into an ordering strategy is superior to the JIT pull strategy and the use of POS data at all levels

Figure 1: The Initial Setup for the Board Game Version of the Beer Game (taken from Adams et al. 2008)



of supply chain. To explore this, cost incurred and profit obtained by each member in a four-echelon supply chain (manufacturer, distributor, wholesaler, and retailer) are computed. For finding the costs incurred and profit obtained, data from spreadsheet beer game simulation developed by Adams et al. (2008) is used. After calculating costs and profit for each player of the supply chain, graphs are plotted between cost versus week (period) and profit versus week for seven different ordering strategies. These graphs have also been plotted for different lead times by Sammidi (2008); however, this paper uses the lead time of two periods.

Sterman (1989) developed an expression for ordering behavior in the beer game in terms of adjustment heuristic that is,

$$IO_t = \hat{L}_t + AS_t + ASL_t$$

Where:

- IO_t - Order rate in time period t,
- $\hat{L}_t$ - Expected demand in period t,
- AS_t - Difference between the desired stock and actual stock in period t, and
- ASL_t - Difference between the desired and actual supply line in time period t.

The anchoring heuristic $\hat{L}_t$ is often determined using exponential smoothing as follows:

$$\hat{L}_t = \theta L_{t-1} + (1-\theta)\hat{L}_{t-1}$$

Where L_{t-1} is the demand for the previous period, $\hat{L}_{t-1}$ is the forecast value of demand for previous period, θ is a parameter varying between 0 and 1.

The adjustment for stock AS_t is the difference between the desired stock S^* and the actual stock S_t multiplied by a parameter α_S ($0 \le \alpha_S \le 1$) specifying the fraction of the difference ordered each period.

$$AS_t = \alpha_s(S^* - S_t)$$

The adjustment for supply line is the difference between desired supply line SL^* and the actual supply line multiplied by a parameter α_{SL} specifying the fraction of the difference ordered each period.

$$ASL_t = \alpha_{SL}(SL^*_t - SL_t)$$

The supply line consists of orders in mail delays, the immediately upstream supplier's backlog, and the material in shipping delays (Adams et al., 2008). We can have for orders: $0 \le \alpha_{SLO} \le 1$; for material: $0 \le \alpha_{SLM} \le 1$; and for upstream backlog $0 \le \alpha_{SLB} \le 1$.

The cost incurred by each member is calculated by finding the various costs involved. The cost includes the price of the product, ordering cost, holding costs or inventory cost, and the backlog cost. The backlog cost is the cost, which the supplier must pay as a penalty if he/she cannot deliver the product within the time actually agreed upon. The backlog cost per item is computed by assuming it to be double the cost of the inventory per item (Nienhaus, Zeigenbein, & Schoensleben, 2006). Thus,

Total cost = (Cost per item*number of items ordered) + Ordering cost + Inventory cost (2*Inventory cost per item*number of backlog items)

The ordering cost per order and inventory cost per item are assumed to be $100 and $0.5, respectively for each member in the four-echelon supply chain. Hence,

Total cost = Price per item*number of items ordered + 100 + 0.5*number of items in Inventory + 2*0.5* number of backlog items.

The value of price per item increases from manufacturer to retailer. The price per item for the manufacturer is assumed to be $10, and then it is increased by 2.5 times $10 when it comes to the distributor and then 2.5 times the price of the distributor for the wholesaler and then again 2.5 times the price of the wholesaler for the retailer. Thus, the price per item for distributor is $25, for wholesaler it is $62.5 and for the retailer it is $156.25. The number of items ordered, the number of items in inventory, and the backlogs values have been taken from the simulation developed by Adams et al. (2008). After finding the total cost incurred for each member, the revenue of each member of the supply chain is calculated. The revenue for the manufacturer is the price that the distributor pays for the product;

Table 1. Anchoring and Adjustment Cases (Adams et al. 2008)

Case	$\hat{L}_t$	AS_t	ASL_t
1	θ =1, (Pull)	α_S =1, (12–(inv–bklg))	None
2	Pull	12 – (inv – bklg)	α_{SLO} =1, α_{SLM} =0, α_{SLB} =0, (Less orders)
3	Pull	12 – (inv – bklg)	α_{SLO} =0, α_{SLM} =1, α_{SLB} =0, (Less material)
4	Pull	12 – (inv – bklg)	α_{SLO} =1, α_{SLM} =1, α_{SLB} =0, (Less material and orders)
5	Pull	12 – (inv – bklg)	α_{SLO} =1, α_{SLM} =1, α_{SLB} =1, (Less material, orders, and upstream supplier's backlog)
6	Pull	α_S =0, None	None
7	POS	Not applicable	Not applicable

the revenue for the distributor is the price that the wholesaler pays for the product; and the revenue for the wholesaler is the price that the retailer pays for the product.

Profit of each member is calculated by deducting their cost incurred from their revenue obtained, and graphs are developed for seven different cases. Sammidi (2008) contains the detailed work. The seven cases are shown in Table 1.

Among the seven cases mentioned, the first five cases demonstrate the reduction in bullwhip effect as more and more information is interpreted into the supply line. The first case uses an anchoring heuristic of ordering what was ordered, which is equivalent to the pull system, but with a stock adjustment of the full difference between the ideal stock of 12 and the inventory level, that is, 12 – (inventory – backlog). This case displays the largest bullwhip effect as shown in Figures 2-3 of all cases studied. Cases 2 – 5 use the same anchoring and stock adjustment heuristics of Case 1, but they have supply line adjustment heuristics that compensate for more and more of the supply line (orders in mail delays, material in shipping delays, and immediate upstream supplier's backlog). As more and more of the supply line is compensated, the bullwhip effect diminishes in Cases 2 – 4 until it is completely eliminated in Case 5, when the entire supply line consisting of the sum of the orders in mail delays, the immediate upstream supplier's backlog, and the material in shipping delays is accounted for.

This paper shows graphs in Figures 2 – 6 for cost and profit versus period (week) for four cases with lead time of two periods. Because profit is revenue minus cost, the profit graph takes into consideration the effect on cost. Hence, there is no need to display the cost versus week graph for each of the cases. Cost and profit for Case 1 are displayed in Figures 2 and 3. Case 1 illustrates the maximum bullwhip effect when no supply chain line information is provided. Case 5 (Figure 4), Case 6 (Figure 5), and Case 7 (Figure 6) show that the bullwhip effect is eliminated. In Case 5, adjustments for supply chain in terms of order delay, material in shipping delay, and upstream backlog have been taken into account. Case 6 is pull strategy, which does not adjust for either stock or supply line. It does not show any bullwhip but produces a steady-state error. This error is better than the bullwhip effect. Also the steady error of Case 6 is slightly better than that of Case 5. In Case 7 there is complete exchange of data between the members of the supply chain, which eliminates the bullwhip effect. However, Case 6 and Case 7 both require discipline and at times are not easy for companies to follow.

Figure 2. Case 1: Cost for Maximum Bullwhip Effect without Supply Line Information

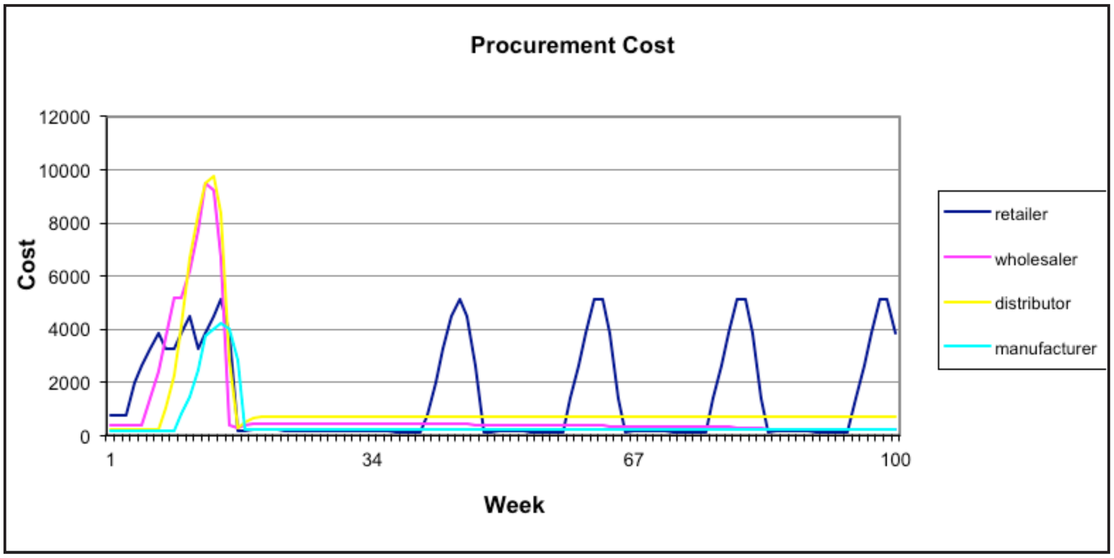


Figure 3. Case 1: Profit for Maximum Bullwhip Effect without Supply Line Information

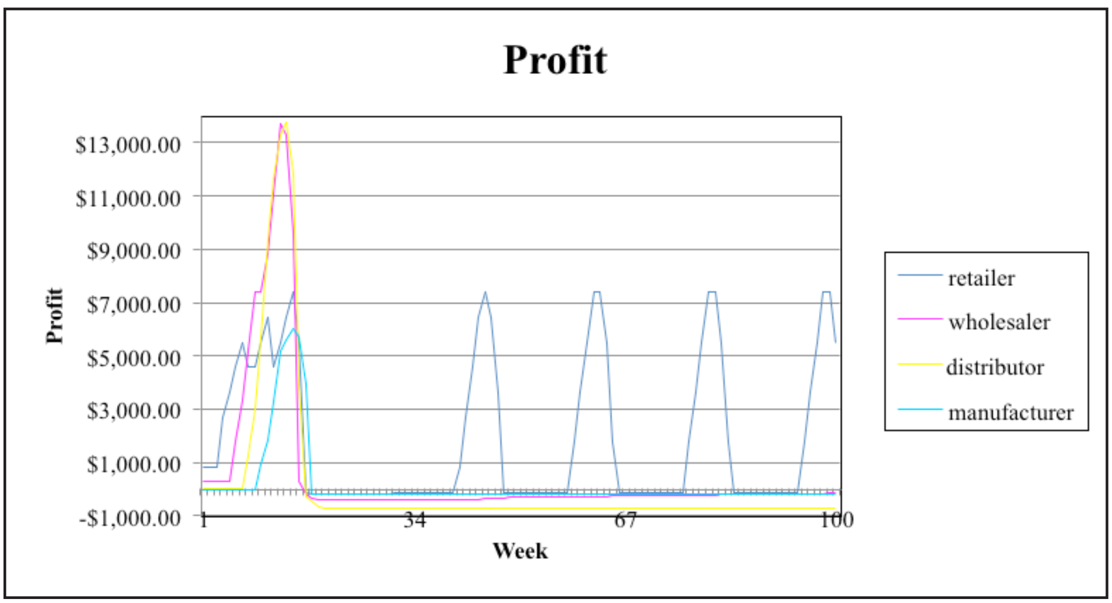


Figure 4. Case 5: Elimination of Bullwhip Effect on Profit by Compensation for Material, Orders, and Upstream Supplier's Backlog in the Supply Line

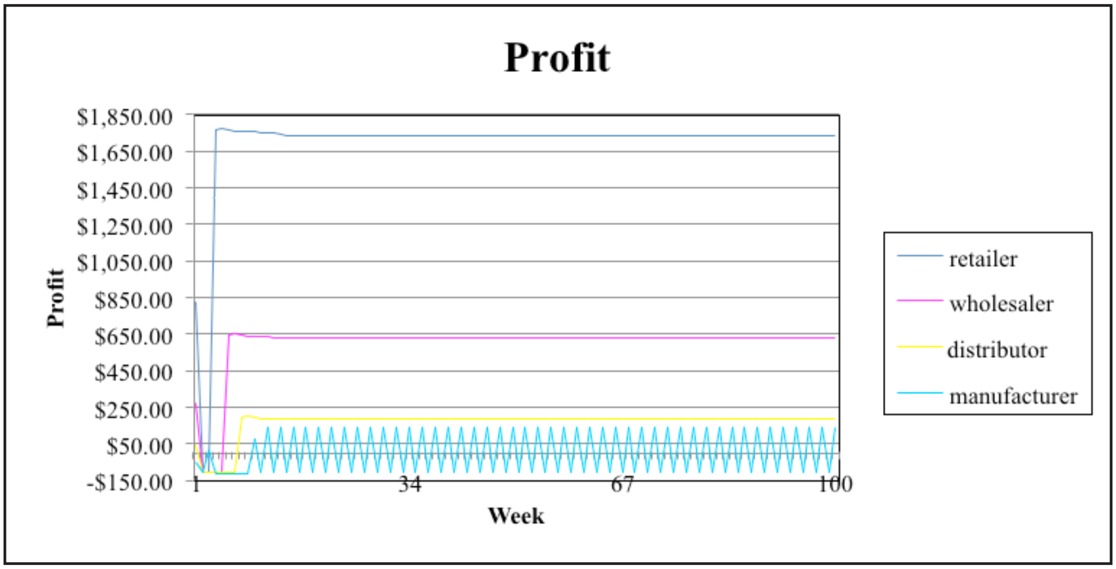


Figure 5. Case 6: Elimination of Bullwhip Effect on Profit by Pull Strategy

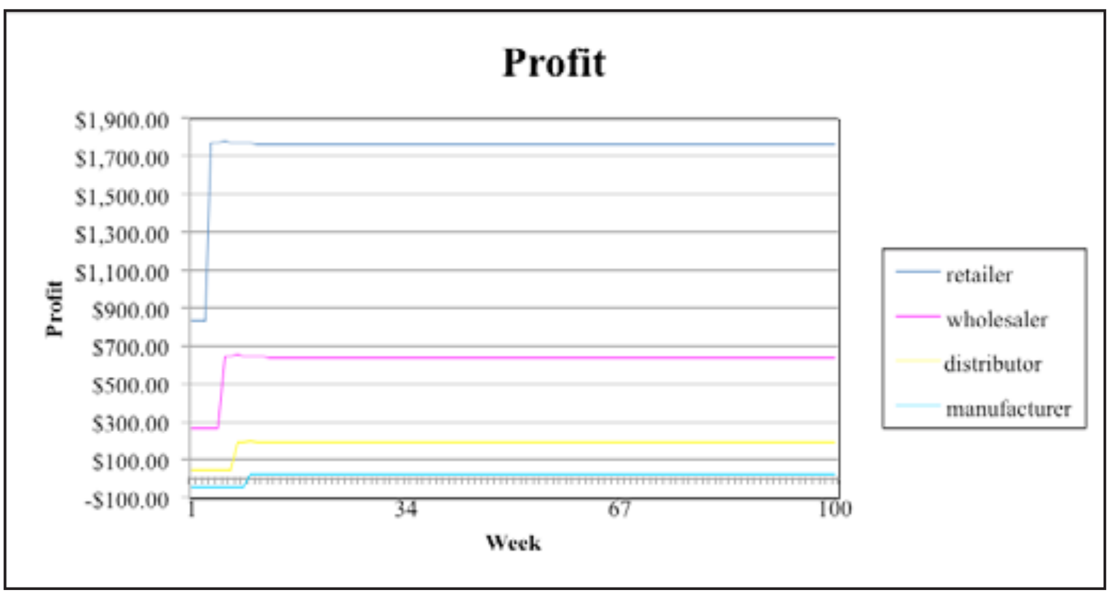
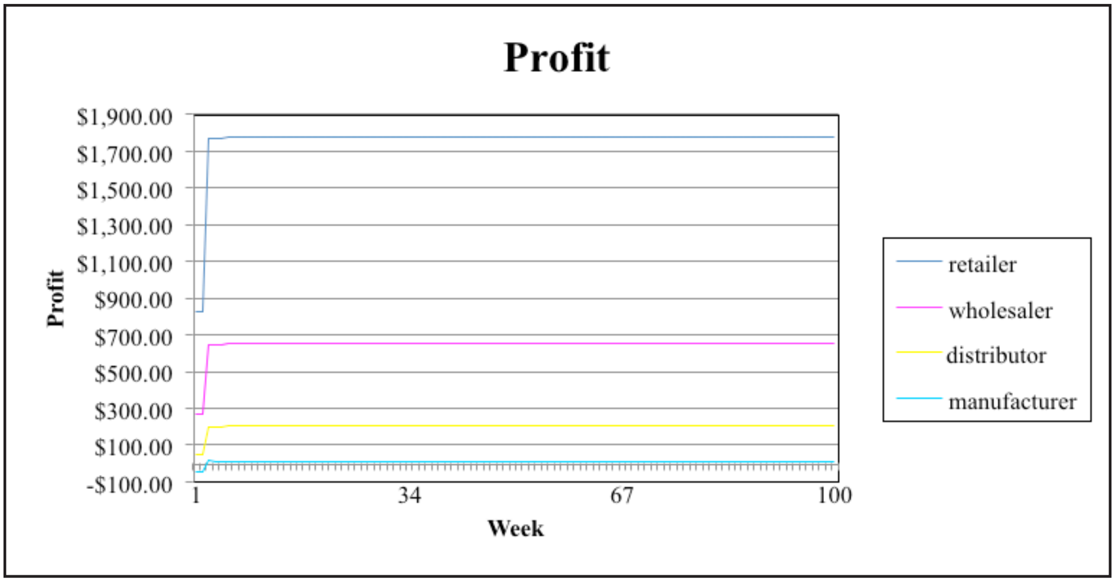


Figure 6. Case 7: POS Eliminates Bullwhip Effect and Backlog



Conclusion

This study is an extension of the work done by Adams et al. (2008), and it uses the beer game spread sheet simulation developed by them. The beer game (Sterman, 1992), shows information and material flow in a four-echelon supply chain. An attempt has been made in the current work to find an ordering strategy that is easy to employ and can minimize the bullwhip effect. Five strategies (Case 1 through Case 5) with different levels of information about inventory and components along the supply line have been compared with the JIT pull strategy (Case 6) and the usage of POS data (Case 7). The cost incurred and profit obtained by each player (manufacturer, distributor, wholesaler, and retailer) of the supply chain for the seven ordering strategies have been determined. Graphs for cost and profit versus time have been plotted.

From the graphs it is evident that as more and more information is provided for the inventory and components along the supply line from Case 1 through Case 5, the bullwhip effect is reduced. Case 1 uses an anchoring heuristic of ordering what was ordered and a stock adjustment to compensate for the difference between the ideal stock and the inventory level. This case shows the largest bullwhip effect. Cases 2 – 5 use the same anchoring and stock adjustment heuristics of Case 1, but have supply line adjustment heuristics that compensate for more and more of the supply line. As more and more of the supply line is compensated, the bullwhip effect diminishes in Cases 2 – 4 until it is completely eliminated in Case 5, when the entire supply line consisting of the sum of the orders in mail delays, the immediate upstream supplier's backlog, and the material in shipping delays is accounted for.

Case 6 is a pull strategy, which does not adjust for either stock or supply line. It does not show any bullwhip, but it produces a steady-state error. This error is better than the bullwhip effect. Also the steady error of Case 6 is slightly better than that of Case 5. In Case 7 there is complete exchange of data between the members of the supply chain, which eliminates the bullwhip effect. Thus, Case 7 where POS data is used is the best strategy that eliminates the bullwhip effect and Case 6 (pull strategy) is the next best. However, Case 6 and Case 7 both require discipline and at times are not easy for companies to follow. POS has an additional issue because of the reluctance between each member of the supply chain to share information. In such circumstances, Case 5 is a reasonable strategy with better applicability.

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References

Adams, J., Flatto, J., & Gardner, L. (2008). Analyzing supply chain performance using beer game. In K. E. Stecke (Ed.), *Operations management education review*: Vol. 2 (pp. 41-68). Scotland, UK: Neilson Journals Publishing.

Adelson, R. M. (1966). The dynamic behavior of linear forecasting and scheduling rules. *OR Quarterly*, 17 (4), 447-462.

Bhattacharya, R., & Bandyopadhyay, S. (2011). A review of the causes of bullwhip effect in a supply chain. *The International Journal of Advanced Manufacturing Technology*, 54 (9-12), 1245-1261.

Cachon, G. P., & Lariviere, M. A. (1999). Capacity choice and allocation: Strategic behaviour and supply chain performance. *Management Science*, 45(8), 1091-1108.

Cangelose, V. E., & Dill, W. R. (1965). Organizations learning: Observations toward a theory. *Administrative Science Quarterly*, 10, 175-203.

Cao, Q., & Siau, K. (1999). Artificial intelligence approach to analyzing the bullwhip effect in supply chains. *Proceedings of the 5th Americas Conference on Information Systems* (pp. 44-45). Milwaukee: AMCIS.

Carlsson, C., & Fuller, R. (2001). Reducing the bullwhip effect by means of intelligent, soft computing methods. *Proceedings of the 34th Annual Hawaii International Conference on System Sciences*. 3-6 Jan 2001, p. 3027. IEEE Computer society.

Chen, F. (1999). Decentralized supply chains subject to information delays. *Management Science*, 45(8), 1016-1090.

Chen, F., Drezner, Z., Ryan, J. K., & Simchi-Levi, D. (2000). Quantifying the bullwhip effect: The Impact of forecasting, lead times, and information. *Management Science,* 46 (3), 436-443.

Chopra, S., & Meindl, P. (2004). *Supply chain management: Strategy, planning and operation*. Englewood Cliffs, NJ: Prentice Hall.

Croson, R., & Donohue, K. (2003). Impact of POS data sharing on supply chain management: An experimental study. *Production and Operations Management*, 13(4), 340-353.

Dejonckheere, J., Disney, S. M., Lambrecht, M. R., & Towill, D. R. (2003). Measuring and avoiding the bullwhip effect: A control theoretic approach. *European Journal of Operational Research*, 147(3), 567-590.

Emmett, S. (2005). Excellence in Warehouse Management: How to Minimize Costs and Maximise Value. Hoboken, NJ: John Wiley & Sons.

Fransoo, J. C., & Wouters, M. J. (2000). Measuring the bullwhip effect in the supply chain. *Supply Chain Management: An International Journal*, 5(2), 78-79.

Goldberg, D. E. (1989). *Genetic algorithms in search, optimization and machine learning*. Boston, MA: Addison-Wesley.

Heizer, J. H., & Render, B. (2001). *Operations management* (6th ed.). Upper Saddle River, NJ: Prentice Hall.

Henkoff, R. (1994). Delivering the goods. *Fortune*, 130(11), 34-47.

Jacobs, F. R. (2000). Playing the beer distribution game over the internet. *Production and Operations Management*, 9(1), 31-39.

Jung, H. D., Ahn, H. S., Ahn, B. H., & Rhee, S. K. (1999). Impacts of buyers' order batching on the supplier's demand correlation and capacity utilization in a branching supply chain. *Production Planning and Control*, 10(5), 472-485.

Kaminsky, P., & Simchi-Levi, D. (1998). A New-computerized Beer game: A tool for teaching the value of integrated supply chain management. In H. Lee & S. M. Ng (Eds.) *Supply chain and technology management* (pp. 216-225). Miami, FL: POMS.

Kumar, S., Chandra, C., & Seppanen, M. S. (2007). Demonstrating supply chain parameter optimization through beer game simulation. *Information Knowledge Systems Management*, 6(4), 291-322.

Ladbury, A. (2008). Supply-chain risks misunderstood, mismanaged: Report. *Business Insurance*, 42(2), 23.

Lee, H. L., Padmanabhan, V., & Whang, S. (2004). Comments on "information distortion in a supply chain: The bullwhip effect." *Management Science*, 50 (12), 1887-1893.

Lee, H. L., Padmanabhan, V., & Whang, S. (1997a). The bullwhip effect in supply chains. Sloan *Management Review*, 38(3), 93-102.

Lee, H.L., Padmanabhan, V., & Whang, S. (1997b). Information distortion in a supply chain: The bullwhip effect. *Management Science*, 43 (4), 546-558.

Lin, P. H., Wong, D. S. H., Jang, S. S., Shieh, S. S., & Chu, J. Z. (2004). Controller design and reduction of bullwhip for a model supply chain system using z-transform analysis. *Journal of Process Control*, 14(5), 487-499.

Machuca, J.A.D., & Barajas, R. P. (2004). The impact of electronic data interchange on reducing bullwhip effect and supply chain inventory costs. *Transportation Research Part E: Logistics and Transportation Review*, 40(3), 209-228.

Moore, S. A., & DeMaagd, K. (2005). Using a genetic program to search for supply chain reordering policies. In U-M. O'Reilly, T. Yu, R. Riolo, & B. Worzel (Eds.), *Genetic programming theory and practice II* (pp. 207-223). NY: Springer.

Moyaux, T., & McBurney, P. (2006). Reduction of the bullwhip effect in supply chains through speculation. In C. Bruun (Ed.), *Advances in artificial economics: The economy as a complex dynamic system*. Lecture Notes in Economics and Mathematical Systems Series, Volume 584 (pp. 77-89). Berlin, Germany: Springer.

Nienhaus, J., Zeigenbein, A., & Schoensleben, P. (2006). How human behaviour amplifies the bullwhip effect. A study based on the beer distribution game online. *Production Planning & Control,* 17(6), 547-557.

O'Donnell, T., Maguire, L., McIvor, R., & Humphreys, P. (2006). Minimizing the bullwhip effect in a supply chain using genetic algorithms. *International Journal of Production Research* , 44(8), 1523-1543.

Sammidi, S. (2008). Cost and profit analysis of supply chain ordering strategies to minimize the bullwhip effect using beer game. Indiana State University: MS in Industrial Technology Major Project.

Sarode, A. D., & Khodke, P. M. (2009). Performance measurement of supply chain management: A decision framework for evaluating and selecting supplier performance in a supply chain. *The International Journal of Applied Management and Technology* , 8 (1), 1-21.

Simchi-Levi, D., Kaminsky, P., & Simchi-Levi., E. (2007). *Designing and managing the supply chain: Concepts, strategies, and case studies* (3rd ed.). Boston, MA: Irwin McGraw-Hill.

Steckel, J. H., Gupta, S., & Banerji, A. (2004). Supply chain decision making: Will shorter cycle times and shared point-of-sale information necessarily help? *Management Science* , 50(4), 458-464.

Sterman, J. D. (1989). Modeling managerial behavior: Misperception of feedback in a dynamic decision making experiment. *Management Science* , 35(3), 321-339.

Sterman, J. (1992). Teaching takes off: Flight simulators for management education. *OR/MS Today*, October, 40-44.

Torres, O. A. C., & Moran, F. A. V. (2006). *The bullwhip effect in supply chains: A review of methods, components and cases*. New York: Palgrave Macmillan.

Towill, D. R., Zhou, L., & Disney, S. M. (2007). Reducing the bullwhip effect: Looking through the appropriate lens. *International Journal of Production Economics* , 108(1-2), 444-453.

Vonk, E., Jain, L. C., & Johnson, R. P. (1997). *Automatic generation of neural network architechture using evolutionary computation*. Advances in fuzzy systems - Applications and theory, Vol. 14. River Edge, NJ: World Scientific.

Warburton, R. D. H., Hodgson, J. P. E, & Kim, Y. K. (2004). *An analytical investigation of the bullwhip effect*. NTC Project: S03-MD13s, National Textile Center Annual Report.

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Perceptions of New Doctoral Graduates on the Future of the Profession

By John Ritz and Gene Martin

Abstract

Advancement of a profession relies heavily on the participation of its members. Leadership roles must be filled at many levels. To effectively prepare future leaders, efforts must be undertaken to educate and mentor them both about their professions and how to lead within them. The authors sought to identify the perceptions of those who recently earned a doctoral degree with focus on technology and engineering education. In the past, this group developed and assumed major roles in leading their education professions. This study reports on new doctoral graduates' perceptions related to the focus of content taught in formalized K-12 technology and engineering education programs, methods used to prepare future technology and engineering teachers, characteristics of their planned professional involvement, and future forecasting for their school subject.

Keywords: New Ph.D. Perceptions, Profession, Technology and Engineering Education

Introduction

Public perceptions and economic circumstances often create disadvantages for the continued offering of K-12 school subjects that are classified as elective courses. In many cases, these elective courses are being eliminated from the school curriculum. This is no more evident than in the data revealed on the school subjects of technology and engineering education.

The number of teachers who teach in technology and engineering education programs has declined from 37,968 in 1995 to 28,310 in 2009, a loss of 9,658 teachers (35.4% decline) in just 14 years (Moye, 2009). The number of university programs that prepare these teachers also has declined from almost 300 in the 1970s to 27 (91% decline) identified in 2008 (Moye, 2009). These factors, plus the societal impacts associated with 9-11, the economic downturn of 2008, and the changing attitudes of the perceived value of belonging and participating in the sponsored activities of organizations, have caused a decline in the memberships of professional organizations (Martin, 2007). With fewer teachers entering the profession and fewer teachers joining professional organizations, how can the school subjects of technology and engineering education and their related professional education organizations keep the profession vibrant and provide the potential for change to meet the needs of their members and the students they serve?

The researchers of this study have been active participants in these school subjects for several decades and the professional organizations that are directly associated with them. They have provided guidance and teacher professional development to support these school subjects throughout their careers. They are very much aware that several universities, albeit a declining number, continue to prepare new professors who will train future teachers for these school subjects. They believe that the new technology and engineering teacher educators graduating from these doctoral programs have the challenge of continuing to prepare teachers for these school subjects to serve future generations of learners. Together, the researchers planned this study to determine the perceptions of new doctoral graduates on a number of issues related to technology and engineering education.

Consequently, this study was conducted for the purpose of determining directions that new graduates might pursue with their subject area's content, methods of future teacher preparation, planned professional involvement, and future forecasting of their school subject. The researchers' goal was to capture new graduates' perspectives about their profession in order to project what might be the future "health" of the profession by the year 2025. The anticipated beneficiaries of this study are individuals who closely identify themselves with mapping a course of action for the profession over the next 12 years. Professionals may use information reported in this study to initiate substantive discussions or even extend existing discussions on the future of the profession and the characteristics of individuals who will lead it.

Review of Literature

Organizations are formed by groups of people who bond together for a common purpose. K-12 schools are organizations, as are universities. Professional associations are organizations. To remain viable, organizations must adapt to changing environments (Senge, 1990). Adaptability is an important characteristic for the survival of any learning organization. Those who practice teaching, either in K-12 or at the university, have had to adapt their programs in order for their programs to remain viable. The associations that support teachers of technology and engineering also require continual change to better support their members.

Historically, professional associations provided a source of professional definition, a forum to increase public awareness, and a role in setting guidelines in preparing a person with appropriate credentials to practice that profession. The associations (a) provided professional development for their members, (b) set standards for educational practice, (c) organized and hosted forums on issues important to the members, and (d) attempted to unify political action campaigns to better position the profession (Phillips & Leahy, 2012). The major associations that represent the profession and technology and engineering education, including their state affiliates, practice many of the cited functions.

However, just as the number of technology and engineering teachers and their teacher preparation programs has been declining since the 1980s, similar reductions in professional memberships across various fields and disciplines have followed the same downward trend (Alotaibi, 2007; Bauman, 2008; Putnam, 2000; Yeager & Kline, 1983). These declines have caused professional organizations to cut services to members, just to survive economically (Martin, 2007). No longer can professional associations meet all the needs of their members. Consequently, this lack of help can cause further declines in memberships as people migrate to other associations they believe can provide the services to meet their individual needs.

Individuals join professional organizations because of the alignment of values they see between themselves, their profession, and the professional organization. The organizations they join often promote similar codes of ethics for professional conduct, work to preserve the subject's public image, and attempt to provide services to keep the professional current with the latest developments occurring within their field (Meltzer, 1996). As a result, people who join professional organizations care about their work within the profession (Rouch, 1999).

People who are perceived as leaders often lead professions and professional organizations. Some are hired as staff and others work as volunteers. Organization boards search for the best professionals to work in these positions to guide their associations in order to provide the best services and voice for their members. As their membership grows and develops professionally, it is most likely that they will improve the overall stature of their professions.

To become a professional leader usually takes years of professional development. A person must not only understand the knowledge base upon which the profession was established, but that person also must be willing to work for the betterment of the profession and its members. A leader must know how to work with others and direct them, get the tasks of the association accomplished, and plan for the future needs of the profession and its members. One function of leadership is thinking about the future (Gilberti, 1999).

When the technology and engineering teaching profession, particularly the Council on Technology and Engineering Teacher Educators (CTETE), began to vision its future, its members understood that new members would be needed to take over the leadership roles of the profession. Observations show that many talented leaders are good performers at their current jobs, leaders in their professions, and possible leaders of other organizations. Some leaders move on to other careers, causing voids in the leadership chain. High-performing members are not always there when associations need them to step into leadership roles as they move on to other career paths. These same observations show us that good leaders also retire, causing voids both at the workplace and in organizational leadership.

Colleges and universities have worked to develop models for the improved preparation of graduates who seek to become faculty members. In some fields, doctoral students take classes and work on research projects with faculty. These research projects sometime model what they will need to do in future faculty member positions. Many of these doctoral students prepare to become faculty, but they do not understand the teaching and service roles required in university positions. This creates problems for them when they transition into becoming teaching faculty members. In 1993, the Council of Graduate Schools and the Association of American Colleges and Universities designed a model labeled as "Preparing Future Faculty"; this program included three core components: "gaining teaching experience; learning about the academic triad of research, teaching, and service; and mentoring" (Richlin & Essington, 2004, p. 149). Its aim was to lessen the transition problems experienced by new doctoral graduates when they were hired to fill university faculty positions.

Most who seek to become professors of technology and engineering education have gained previous teaching experience and learned the best practices of teaching through degree work and on-the-job training. Many have student taught and operated their own classrooms/laboratories. These doctoral students could learn the research and service branches of the university triad by working closely with faculty and research mentors. However, reports indicate that not all new faculty are mentored well to become academic citizens (Gaff, 2002) or learn the other important qualifications needed for a faculty position.

Through the leadership of William Havice of Clemson University and Roger Hill of The University of Georgia, the Council on Technology and Engineering Teacher Education (CTETE) initiated the Twenty-first Century Leadership Academy (CLA) Program. Beginning in 2006, this program was developed "to facilitate a sense of community and provide activities and resources to support scholarly and professional development opportunities for groups of early career technology education faculty" (Havice & Hill, 2012, para. 1). One of the goals of the program was to "grow our own leaders." The success of this program led it to become a part of the leadership program in the International Technology and Engineering Educators Association's (ITEEA) strategic plan in 2010. "One of the purposes of this program is to provide initial experiences to potential leaders so that they can evolve to become the next generation of professional leaders" (Havice & Hill, 2012, para. 4).

The Twenty-first Century Leadership Academy Program

> This is a program designed to create tomorrow's most successful and respected technology and engineering leaders, consultants, and strategic thinkers. As leaders, we need to create the future. This program incorporates knowledge and experiences from education leaders and other experts using practical and innovative advice on how leaders make a difference. Participants are involved in important dialogue using the best wisdom from experts and practitioners across sectors of the profession.
>
> The aim of the program is to help technology and engineering educators gain additional skills to better deal with issues of performance, how systems and associations work, the role of finances in decision-making, and how to merge ideas and ambitions in a positive manner. The 21st CLA program provides a balance of practical and inspirational ideas to individuals who want to be leaders in the association and profession. (Havice & Hill, 2012, para. 2-3).

With the continued preparation of new doctoral graduates with focused study in the preparation of technology and engineering educators and the added benefits some of these graduates have gained through participation in the Twenty-first Century Leadership Academy Program, the researchers sought to determine the perspectives of these new professionals about the future of the school subjects technology and engineering education. (The researchers are not aware of any prior studies on this topic.) This study was designed during summer 2012 and administered in the fall of 2012. The researchers identified 59 new doctoral graduates who were prepared during the past five years in this teaching area. The researchers believe this population represents most (95-98%) graduates awarded doctoral degrees during the past five years in this field. This is based on: (a) information from program leaders at universities that offer doctoral degree programs with concentrated study in technology and engineering education, (b) a list of fellows who completed degree work through support of the National Center for Engineering and Technology Education, and (c) a list of participants who took part in ITEEA's Twenty-first Century Leadership Academy Program.

Research Design

The researchers selected the survey method, a nonexperimental quantitative research tool, as the research design for the study. Fraenkel, Wallen, and Hyun (2012) identified the survey as a method to "describe the characteristics of a population" (p. 393). These authors noted that in other types of research "the population as a whole is rarely studied" (p. 393), the survey method allows for a "carefully selected sample of respondents" (p. 394) to be surveyed, and a "description of the population is inferred from what is found out about the sample" (p. 394). For purposes of this study, a cross-sectional survey was administered to gather information from a predetermined population at a predetermined point in time. Gay, Mills, and Airasian (2012) noted that cross-sectional designs are "effective for providing a snapshot of the current behaviors, attitudes, and beliefs in a population" (p. 185). Creswell (2012) stated that a cross-sectional survey design has the "advantage of measuring current attitudes or practices" (p. 377).

Procedure

The researchers administered a structured 12-question survey (followed by 5 demographic-related questions) using SurveyMonkey™. Wiersma and Jurs (2009) underscored the importance of collecting demographic data in terms of classifying variables for further analysis. Gay et al. (2012) stated the importance of designing surveys that are brief, easy to respond to, and address a specific research topic. The survey for this study was administered in November 2012; two additional follow-up letters were sent to the invitees. In order to ensure anonymity of the participants, a URL to the survey was provided in the initial letter of invitation to participate and in follow-up letters. At no time during the conduct of the study did the researchers know which participants did or did not respond to the survey. In the final analysis, 34 of the 56 invitees or 60.7% selected to respond (correct email addresses could not be identified for three graduates). Although the response rate is not statistically significant (Patten, 2012), the information provided by the respondents was revealing because it provided clues about the health, vitality, and possibly the future of the technology and engineering education teaching profession as seen through the lens of recent doctoral graduates. No incentives were provided to the participants, and they were reminded in their letter of invitation to participate that there were no direct benefits to them by participating. Finally, invitees were informed that their responses would be aggregated with the responses from all other participants, so there would be minimal risk to them as a participant.

Prior to commencing the study, the researchers assumed that the participants were capable of identifying (a) the focus of content taught in a formalized K-12 technology and engineering education program, (b) methods of future teacher preparation, (c) characteristics of their professional involvement, and (d) future forecasting for their school subject. The researchers also assumed the participants understood the intent of each survey question and their responses to the questions would reflect their individual insights and perspectives about the profession. Finally, the researchers assumed that each survey question contained only one idea or question, used neutral (unambiguous) language so as not to lead a respondent to respond in a specific way, and contained response options that were simple, clear, and consistent.

Findings

The population for this study was a group of recent doctoral graduates ($N = 34$) who were nominated by lead professors at seven universities that offer the doctoral degree in technology and engineering education or the graduates were in a specialized sponsored program. For example, a qualified doctoral graduate was one who graduated (Ph.D. or Ed.D.) within the past five years from one of the following institutions: Colorado State University, North Carolina State University, Old Dominion University, The Ohio State University, The University of Georgia, Utah State University, and Virginia Polytechnic and State University. Some graduates may have completed their degrees under the auspices of the National Center for Engineering and Technology Education (NCETE) and may not be part of the seven purposely selected institutions. Finally, some graduates participated in the International Technology and Engineering Educators Association's (ITEEA) Twenty-first Century Leadership Academy Program and graduated from one of the purposely selected institutions and/or participated in the NCETE program. In a select few cases, a participant in the study may have been involved in more than one of the preceding categories. The researchers collected demographic data from the participants, and analyses of the data are provided in Table 1.

Data were gathered and analyzed from the participants' responses to the 12 survey questions. Part 1 of the survey focused on what is currently happening in the profession – the "here and now" – and the role the participants currently serve in their profession; Part 2 focused on the future of the profession from the participants' perspectives. A summary of the data for Part 1 of the study is first reported, followed by a summary of the data for Part 2.

Part 1

When asked to identify what should be the focus of content taught in a formalized K-12 technology and engineering education program, the participants were provided five choices to

Table 1. Population Demographics

Demographic	Selection	Number	Percent
Gender (*n* = 33)	Female	7	21.2
	Male	26	78.8
Age (*n* = 33)	20-30	1	3.0
	31-40	16	48.5
	41-50	8	24.2
	51-60	7	21.2
	61+	1	3.0
Area of Professional Interest (*n* = 33)	Post-Secondary	16	48.5
	High School	11	33.3
	Middle School	3	9.1
	Elementary School	3	9.1
Current Position (*n* = 26)	Teacher Educator	15	57.7
	Elementary Teacher	6	23.1
	Supervisor	2	7.7
	Private Sector	2	7.7
	Full-Time Student	1	3.8
CTETE 21st Century Leader Program Participant (*n* = 33)	Yes	18	54.5
	No	15	45.5

Note: *N* = 34. One respondent chose not to answer the demographic questions. It appears that eight participants work in the private sector by not selecting a response for current educational positions.

select from, and they were instructed to select "all that apply." Any participant could select one or more responses from the following choices: technological literacy, workforce education, engineering education, STEM integration, and "other." All 34 participants responded to the question. Twenty-five or 73.5% of the responses indicated the focus should be on technological literacy, 24 or 70.6% indicated the focus should be on STEM integration, 20 or 58.8% indicated the focus should be on engineering design, and 14 or 41.2% indicated the focus should be on workforce education. Three responses were recorded for the "other" category, and those written comments focused on content that might be included within the curriculum.

The second question focused on instructional strategies and what should be the focus of these strategies in a formalized K-12 technology and engineering education program. The researchers provided the participants four choices, and they were instructed to select "all that apply." The four choices were project-based, design-based, contextual, and "other." All 34 participants responded to the question. The project-based instructional strategy received the highest response at 85.3%, whereas designed-based was selected by 64.7% and contextual was selected by 61.8% of the participants. The "other" category was selected by five participants, and their responses included strategies such as inquiry-based, problem-based, hands-on (real world design and build), problem solving-based, and contest-based.

The researchers then focused on having the participants identify the primary audience for a formalized instructional program in technology

Table 2. Part 1, Current Activity within the Profession

Item	Selection	Number	Percent
1. Content for K-12 T/E Ed. (*n* = 34)	Technological Literacy	25	73.5
	Workforce Education	14	41.2
	Engineering Design	20	58.8
	STEM Integration	24	70.6
2. Focus of Instructional Strategies (*n* = 34)	Project-based	29	85.3
	Design-based	22	64.7
	Contextual	21	61.8
3. Primary Teaching Audience (*n* = 34)	Elementary School	1	02.9
	Middle School	2	05.9
	High School	3	08.8
	Secondary School	10	29.4
	Post-Secondary School	0	00.0
	All Levels	18	23.9
4. Journals Regularly Read (*n* = 29)	*Technology and Engineering Teacher*	23	79.3
	Children's Technology and Engineering	6	20.7
	Prism Magazine	6	20.7
	Journal of Technology Education	23	79.3
	Journal of Technology Studies	7	24.1

Note: *N* = 34. These numbers exceed the *N* value and 100%, since respondents could select more than one choice for these questions.

and engineering education. The participants were instructed to "select only one" from the following categories: elementary school students, middle school students, high school students, secondary students (middle and high school), post-secondary students, and all of the above identified populations. All 34 participants responded to the question. The participants believe that all elementary, middle, high school, and post-secondary students should be the primary audiences as this category was acknowledged by 53.9% of the participants. Only 29.4% of the participants selected secondary students (middle and high school) as the primary audience.

Professional publications provide members with a vehicle to share and gain new knowledge and to add to the knowledge base in their discipline. The researchers asked the participants which professional publications best described them as a regular reader of those publications. Interestingly, of the 34 individuals who participated in the study, five individuals chose to skip this question and not respond. Of those individuals who responded, two publications received the highest response. *The Technology and Engineering Teacher* and the *Journal of Technology Education* were each selected by 79.3% of the respondents. *The Journal of Technology Studies* was selected by 24.1% of the respondents and *Children's Technology and Engineering* and *Prism Magazine* were each selected by 20.7% of the respondents. Participants were invited to identify other publications that were not part of the forced choices. *The Journal of Engineering Education, Journal of Learning Sciences, International Journal of Technology and Design Education*, and CTETE yearbooks were each identified. Table 2 summarizes data on the perceptions of recent doctoral graduates regarding current activities within the technology and engineering education professions.

Part 2

Part 2 of the survey instructed the participants to project to the year 2025 and then respond to a series of questions that focused on the future of the profession. For example, the researchers asked the participants to focus on teacher certification and how future technology and engineering educators will become certified (licensed) as classroom teachers. Thirty-two of the 34 participants responded to this question. The participants were instructed to select only one descriptor from the following statements and the response rate and n value follow each statement. Some chose to clarify their selection through the "other" category.

- A 4-year campus-based program, much like we have today in education; 40.6%, $n = 13$
- A 5-year campus-based program, with a major in industrial technology, engineering, or other similar major; 18.8%, $n = 6$
- Licensure add-ons to an existing degree program; 28.1%, $n = 9$
- Documenting academic qualifications through professional certification testing; 12.5%, $n = 4$
- Other; $n = 6$. Hybrids of the above options were mentioned, including combinations that entailed focus on STEM education.

Once the participants indicated how future teachers would be certified or licensed, they were then asked "where" they will receive their certification and teacher training. Thirty-three of the 34 participants responded to this question, and they could select "all that apply" from the following statements. The response rate and n value follow each statement.

- In brick and mortar university classroom/laboratories; 54.5%, $n = 18$
- Via distance learning technologies; 27.3%, $n = 9$
- Hybrid systems that involve blended methods of instructional delivery; 75.8%, $n = 25$
- Through an external testing organization; 0.0%, $n = 0$
- Other; 6%, $n = 2$. Both thought that online training was a poor option for the preparation of teachers.

Once teachers are certified, professional development becomes an important part of their tenure as a teacher. The researchers asked the participants to identify where technology and engineering practicing teachers will receive their professional development. Thirty-three of the 34 participants responded to this question, and they could select “all that apply” from the following statements. The response rate and n value follow each statement.

- State/district/city supervisors; 51.5%, $n = 17$
- Commercial vendors; 27.3%, n = 9
- National professional associations; 63.6%, $n = 21$
- State professional associations; 45.5%, $n = 15$
- Local professional associations; 33.3%, $n = 11$
- Teacher education institutions; 69.7%, $n = 23$
- Distance learning providers; 33.3%, $n = 11$
- Other; 0%

Historically, professional associations played a key role in serving the members they represent. Arguably, some associations are the lifeblood of their professions. The researchers sought to identify the professional associations that participants thought they would be members of in 2025. Thirty-two of the 34 participants responded to this question, and they could select “all that apply” from the following statements. The response rate and n value follow each statement.

- ASEE – American Society for Engineering Education; 68.8%, $n = 22$
- ITEEA – International Technology and Engineering Educators Association; 75%, $n = 24$
- CC of ITEEA – Children Council of ITEEA; 18.8%, $n = 6$
- CSL – Council for Supervision and Leadership of ITEEA; 12.5%, $n = 4$
- CTETE – Council on Technology and Engineering Teacher Educators of ITEEA; 50.0%, $n = 16$
- State-level Technology and Engineering Associations; 43.8%, $n = 14$
- STEM Associations (e.g., NSTA – National Science Teachers Association, NCTM – National Council of Teachers of Mathematics); 56.33%, $n = 18$
- Other; 21.8%, $n = 7$. Some of the respondents selected other associations that are related to technical professions but whose mission may not necessarily be directly supportive of education. This may show that not all who complete these specific degrees pursue employment within educational fields.

Being a member of a professional association does not necessarily imply that this person attends meetings of that association. The researchers sought to identify which association conferences the participants would be attending in 2025. Twenty-nine of the 34 participants responded to this question, and they could select “all that apply” from the following statements. The response rate and n value follow each statement.

- ASEE – American Society for Engineering Education; 62.1%, $n = 18$
- ITEEA – International Technology and Engineering Educators Association; 79.3%, $n = 23$
- PATT – Pupils Attitudes Towards Technology; 13.8%, $n = 4$
- State-level technology and engineering conferences; 58.6%, $n = 17$
- TERC – Technology Education Research Conference; 17.5%, $n = 5$
- Other; 31%, $n = 9$. Others included Mississippi Valley Conference, Southeastern Technology Education Conference, International Society for Technology Education, Association for Career and Technical Education, and others.

People join professional associations for a variety of reasons. For example, some may join to receive a publication, while others join because they want to attend meetings. Still others join so that they might publish in the journal of that association. The researchers inquired as to the publications the participants would be publishing in by 2025. Thirty of the 34 participants responded to this question, and they could select “all that apply” from the following statements. The response rate and n value follow each statement.

- *Technology and Engineering Teacher*; 73.3%, $n = 22$
- *Journal of Technology Education*; 86.7%, $n = 26$
- *Journal of Technology Studies*; 30%, $n = 9$
- *International Journal for Technology and Design Education*; 40%, $n = 12$

- *Australiasian Journal of Technology Education*; 3.3%, *n* = 1
- *Prism Magazine*; 10%, *n* = 3
- Other; 40%, *n* = 12. A number of participants listed many of the above journals plus others, including *Journal of Engineering Education* (3 responses), *Children's Engineering and Technology* (3 responses), and *Journal of STEM Education* (2 responses).

Table 3 provides a summary of perspectives of doctoral graduates related to the future of the profession.

The researchers inquired what the participants foresee as their role in the profession in the year 2025. They were provided some descriptive statements that represent different levels of activity. Thirty-two of the 34 participants responded to the question, and they could select "all that apply" from the following statements. The response rate and *n* value follow each statement.

- I believe I will hold or have held key leadership positions in ASEE – American Society for Engineering Education; 43.8%, *n* = 14
- I believe I will hold or have held key leadership positions in CC of ITEEA – Children Council of ITEEA; 25%, *n* = 8
- I believe I will hold or have held key leadership positions in CSL – Council for Supervision and Leadership; 12.5%, *n* = 4
- I believe I will hold or have held key leadership positions in CTETE – Council for Technology and Engineering Teacher Educators; 37.5%, *n* = 12
- I believe I will hold or have held key leadership positions in ITEEA – International Technology and Engineering Educators Association; 56.3%, *n* = 18
- I believe I will hold or have held key leadership positions in state-level technology and engineering education associations; 50%, *n* = 16
- I believe I will hold or have held key leadership positions in STEM Associations (e.g., NSTA – National Science Teachers Association, NCTM – National Council of Teachers of Mathematics); 34.4%, *n* = 11
- I do not envision myself serving in key leadership positions in professional associations; 6.3%, *n* = 2

Finally, the last question, but maybe the most important question: what did the participants project as the future of the technology and engineering education profession by the year 2025. Thirty-three of the 34 participants responded to the question, and they could select "only one" statement from the following choices.

- The profession will look very similar to what it looks like today; that is, it will be a vibrant profession with a core of members who are able to sustain it; 30.3%, *n* = 10
- The profession as we know it today will be replaced by STEM; 39.4%, *n* = 13
- The profession will be integrated into the science profession; 18.2%, *n* = 6
- Technology and engineering education will disappear as a school subject; 12.1%, *n* = 4

Discussion and Conclusions

What did we learn when we sought the informed opinions of what may be the next generation of individuals to lead this profession? Did these individuals identify some new directions for this profession? Did they reinforce the need to support the initiatives that the profession's leaders are currently pursuing? The researchers believe that data provided by the participants in this study provide much insight about current and future initiatives and it behooves the profession's leaders, current and future, to be apprised of what the next generation is suggesting.

As data from this study were reviewed, analyzed, and synthesized, the researchers reached several conclusions. First, there is general agreement among the participants that technological literacy, STEM integration, and engineering design are important foci for content taught in formalized K-12 technology and engineering education programs. Each one of these foci is identified by more than 50% of the participants in the study. This conclusion

Item	Responses	Number	Percent
5. Teacher Certification Pathways	4-year campus program	13	40.6
	5-year campus program with industry/engineering major	6	18.8
	License add-on	9	28.1
	Certification testing	4	12.5
6. Certification and Training Options	On university campus	18	54.5
	Via distance learning	9	27.3
	Hybrid delivery system	25	75.8
	Testing organization	0	00.0
7. Professional Development Providers	State/district supervisors	17	51.5
	Commercial vendors	9	27.3
	National professional associations	21	63.6
	State professional associations	15	45.5
	Local professional associations	11	33.3
	Teacher education institutions	23	69.7
	Distance learning providers	11	33.3
8. Member of which Professional Organization	ASEE	22	68.8
	ITEEA	24	75.0
	Children's Council (ITEEA)	6	18.8
	Council for Supervision and Leadership (ITEEA)	4	12.5
	Council for Teacher Educators (CTETE)	16	50.0
	State-level technology and engineering association	14	43.8
	STEM associations	18	56.3
9. Conference Attendance	ASEE	18	62.1
	ITEEA	23	79.3
	PATT	4	13.8
	State level	17	58.6
	TERC	5	17.2
10. Publications You Would Seek to Publish	*Technology and Engineering Teacher*	22	73.3
	Journal for Technology Education	26	86.7
	Journal of Technology Studies	9	30.0
	International Journal for Technology and Design Education	12	40.0
	Australasian Journal for Technology Education	1	03.3
	Prism Magazine	3	10.0

Note: $N = 34$. Respondents could have more than one response to questions posed.

is supported in the literature (Bybee, 2013; ITEA, 2000; Wicklein, 2006). Second, there is also general agreement on what should be the foci of instructional strategies offered in formalized K-12 technology and engineering education programs. Project-based, design-based, and contextual learning experiences were identified by more than 50% of the participants as important foci of instructional strategies. Third, the audience for engineering and technology education has been a topic of discussion since the subjects' inception. The participants' responses further underscored that the primary "audience" may continue to be a topic of discussion well into the future. The only descriptor selected by more than 50% of the participants was "all of the above," which simply extends the conversation on who these programs are designed to serve. This conclusion is also supported by the ITEA (2000) and Ritz (2011). Fourth, the researchers attempted to determine which publications the participants regularly read as part of their professional growth and development. It was clear that the only two publications were commonly identified in the current technology and engineering education environment: *Technology and Engineering Teacher* and *Journal of Technology Education*. Both publications were read regularly by 79.3% of the respondents.

Fifth, the researchers wanted to find out how future technology and engineering educators will become certified (licensed) as classroom teachers. There was no agreement among the participants. The 4-year campus-based program received the highest response rate (40.6%). Of those participants who chose the "other" category, there was no agreement in their written responses. Sixth, when asked where classroom teachers will receive their certification, hybrid systems involving blended methods of instructional delivery received the greatest response (75.8%), and 54.5% of the participants believed that certification and training would occur in brick and mortar university classroom/laboratories. Do the responses to this question reveal important information about the future of our delivery systems in technology and engineering education? Do institutions and professors need to get more aggressive in designing alternative delivery modes of instruction? Seventh, once we learned the participants' perspectives on how future teachers will be certified, future teachers must engage in continuous professional development. The participants believed that professional development would be provided by the national professional associations (63.6%). This is surprising because our national professional associations are experiencing a decline in membership and a decline in conference attendance. The participants (51.5%) thought that state/district/city supervisors would provide professional development, but once again, many states/districts/cities have either consolidated their supervisory positions or eliminated them to cut costs. Commercial vendors, state professional associations, and local professional associations did not meet the greater than 50% threshold established by the researchers to be considered as a viable alternative to providing professional development. These findings are also supported by those of Devier (1999), Karseth and Nerland (2007), and Leahy (2002). Eighth, the long-term viability of professional associations is always a concern of the leaders of these associations and to the associations' membership (Martin, 2007; Reeve, 1999). Strong membership levels are vitally important to our associations. Will the participants of this study be members of professional associations in 2025 that exist today? Three associations received greater than 50% responses from the participants: ITEEA (75%), ASEE (68.8%), and STEM associations (56.3%). The researchers did not find the selection of ITEEA, ASEE, and STEM associations surprising; however, CTETE did not meet the greater than 50% threshold. It was surprising that the association that has been historically associated with doctoral graduates was not to be viewed as a future association of the graduates. Ninth, it appears that participants in this study will be regular conference attendees of their professional associations' conferences: ITEEA (79.3%), ASEE (62.1%), and state-level technology and engineering conferences (58.6%). Not surprising to the researchers, the two association conferences (TERC and PATT) that are hosted outside the United States received only a small amount of attention from the participants. Tenth, the researchers asked the participants which professional publications they planned to publish in by 2025. Two publications, *Technology and Engineering Teacher* (73.3%) and *Journal of Technology Education* (86.7%)

exceeded the greater than 50% threshold established by the researchers. Surprisingly, even though 68.8% of the participants plan to be members of the ASEE, only 10% envisioned publishing in *Prism Magazine* by 2025.

Individuals who select to serve in leadership positions in their professional associations provide a valuable service to their members. Surprisingly, except for ITEEA, which received a response rate of 56.3%, participants in the study do not envision themselves serving in key leadership positions. Where will our professional associations find individuals to serve in key leadership positions? It appears these individuals may not come from the population represented in this study. Finally, and maybe the most important question asked in this study, what is the future of the technology and engineering education profession? Unfortunately, there is no clear agreement among the participants in this study. The participants were divided as to whether the profession as we know it today will (a) be replaced by STEM, (b) be very similar to what it looks like today, or (c) be integrated into the science school subjects. Will technology and engineering education disappear as school subjects? Of the participants, 12.1% believe they will disappear.

Recommendations for Further Research

The population for this study was a group of recent doctoral graduates (N = 34). It is clear they provided valuable information that may ultimately lead to substantive discussions about the core principles that guide the profession. Future researchers may wish to consider the findings of this study and develop a new and improved set of data. They may also wish to expand the size of the sample to include other populations to ascertain the professional judgments of a broader audience of practicing technology and engineering educators. Researchers may also wish to further dissect the findings of the study, delve more deeply into the current findings of one or more questions for deeper meanings and understandings, and/or simply pose the same questions via a different voice. Finally, researchers may wish to conduct a qualitative study that leads to in-depth interviews and a more in-depth analysis of the participants' initial responses.

Summary

The researchers selected the survey as the research design of choice to solicit specific information from a group of purposely selected graduates of doctoral degree granting institutions. The participants' responses to the survey questions provide quality information about the future of the technology and engineering education professions. In addition, information gleaned from this study may be helpful to professional leaders as they develop their strategic plans and make strategic decisions about the technology and engineering education subjects.

What was learned from this study? In some cases the participants were comfortable with the present direction of their profession. Their responses to other questions, however, left the researchers somewhat puzzled about this profession's future and their roles in that future. For example, they believe in the future of ITEEA and they feel comfortable with its two primary publications, but they do not necessarily feel comfortable with the teacher education affiliate (CTETE) of ITEEA. Participants plan to attend conferences of other professional associations, but they do not see themselves necessarily publishing in the literature of those same associations or leading those associations by holding key leadership positions. Finally, there was no consensus about the future of technology and engineering education in the year 2025. The larger message of the survey to all in this profession is the following uncertainty: Should we be alarmed by the message these graduates conveyed to us?

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References

Alotaibi, M. (2007). Factors affecting nurses' decisions to join their professional association. *International Nursing Review*, *54*, 160-165.

Bauman, S. (2008). To join or not to join: School counselors as a case study in professional membership. *Journal of Counseling & Development*, *86*, 164-177.

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. Arlington, VA: National Science Teachers Association.

Creswell, J. W. (2012). *Educational research* (4th ed). New York: Pearson.

Devier, D. H. (1999). Fostering a professional culture in technology education. In A. F. Gilberti & D. L. Rouch, *Advancing professionalism in technology education* (pp. 251-270). New York: Glencoe McGraw-Hill.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education* (8th ed). New York: McGraw-Hill.

Gaff, J. G. (2002). Preparing future faculty and doctoral education. *Change, 34*(6), 63-66.

Gay, L. R., Mills, G. E., & Airasian, P. (2012). *Educational research* (10th ed). New York: Pearson.

Gilberti, A. F. (1999). The need for professionalism in technology education: Challenges for the future. In A. F. Gilberti & D. L. Rouch, *Advancing professionalism in technology education* (pp. 1-12). New York: Glencoe McGraw-Hill.

Havice, W., & Hill, R. (2012). Foundation for technology and engineering education, international technology and engineering educators association, and council on technology teacher education 21st century leadership academy. Retrieved from: http://www.iteea.org/Membership/21CenturyLeaders/LeadershipAcademyApplication2014.pdf

International Technology Education Association (ITEA). (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

Karseth, B., & Nerland, M. (2007). Building professionalism in a knowledge society: Examining discourse of knowledge in four professional associations. *Journal of Education and Work*, 20, 335-355.

Leahy, M. J. (2002). Professionalism in rehabilitation counseling: A retrospective review. *Journal of Rehabilitation Administration, 26*, 99-109.

Martin, B. (2007). A closer look at three association super-trends. *Journal of Association Leadership*. Retrieved from: http://www.asaecenter.org/PublicationsResources/ JALArticleDetail.cfm?itemnumber=25246

Meltzer, M. (1996). Promoting professionalism. *Atlanta Business Chronicle*. Retrieved from: http://cgi.amcity.com/atlanta/stories/111896/focus1.html

Moye, J. J. (2009). Technology education teacher supply and demand—a critical situation. *The Technology Teacher*, 69(1), 30-36.

Patten, M. L. (2012). *Understanding research methods*. Glendale, CA: Pyrczak Publishing.

Phillips, B. N., & Leahy, M. J. (2012). Prediction of membership in rehabilitation counseling professional associations. *Rehabilitation Counseling Bulletin, 55*(4), 207-218.

Putnam, R. D. (2000). *Bowling alone*. New York: Simon & Shuster.

Reeve, E. M. (1999). Professional associations, organizations & other growth opportunities. In A. F. Gilberti & D. L. Rouch, *Advancing professionalism in technology education* (pp. 69-96). New York: Glencoe McGraw-Hill.

Richlin, L., & Essington, A. (2004). Faculty learning communities for preparing future faculty. *New Directions for Teaching and Learning, 97*, 149-157.

Ritz, J. M. (2011). A focus on technological literacy in higher education. *The Journal of Technology Studies, 37*(1), 31-40.

Rouch, D. L. (1999). Professionalism and leadership in technology education. In A. F. Gilberti & D. L. Rouch, *Advancing professionalism in technology education* (pp. 15-32). New York: Glencoe McGraw-Hill.

Senge, P. M. (1990). *The fifth discipline: The art and practice of the learning organization*. New York: Doubleday.

Wicklein, R. C. (2006). Five good reason for engineering design as the focus for technology education. *The Technology Teacher, 65*(7), 25-29.

Wiersma, W., & Jurs, S. G. (2009). *Research methods in education* (9th ed). Boston: Allyn and Bacon.

Yeager, S. J., & Kline, M. (1983). Professional association membership of nurses: Factors affecting membership and the decision to join an association. *Research in Nursing & Health, 6*, 45-52.

Feasibility Assessment of Using the KIP System to Achieve an Energy-Savings Potential for an Electronic Marquee

By Wen-Fu Pan, Shih-Chun Tu, Mei-Ying Chien, and Ya-Moo Zhang

Abstract

Conventional electronic marquees continue to consume energy even without a human presence. The purpose of this study is to assess energy-savings potential via the installation of the Kinect and IP Power integrated system (KIP) on an electronic marquee; this system will transfer the consumption data for total electricity to electricity-monitoring software (EZ-HD) using a smart meter (EZ-RE) and the ZigBee USB Dongle. An experiment was conducted at one school entrance for two periods during 10 school months, and it was found that the hourly electricity consumption rate for the original electronic marquee system was 1.25 kWh. After the KIP system was installed, the electronic marquee was activated only during human presence, and the hourly electricity consumption rate was 0.97 kWh, providing an average electricity savings rate of 22.4%. The results suggest that the KIP system can help to reduce the consumption of electricity for electronic marquees. Compared to infrared sensor parts used in the past as power switches for electronic equipment, the advantage of the KIP system is that it can distinguish a human presence and would not be interfered by moving objects or animals. In addition, the KIP system has a wider detection range and allows the users to program and detect different electricity-saving contexts and configurations for electronic equipment in different venues according to their individual needs. Therefore, through this test and assessment, we suggest that it is feasible to apply the KIP system in automatic lighting devices, televisions, air conditioners, or security monitoring systems.

Keywords: Electricity-Savings Designs; IP Power; Kinect; Smart Meters

Introduction

For a long time, reducing electricity and energy use has been a primary strategy for reducing the consumption of global energy and carbon emissions; thus, the research related to designing architectural spaces with electricity-savings effect has always received strong attention (Harvey, 2009). For example, regarding electricity-efficient or electricity-savings building materials, Sadineni, Madala, and Boehm (2011) compared the electricity-savings potential of trombe, ventilated, and glazed wall materials, and they found that air tightness and infiltration of the materials were critical factors that influenced electricity savings. Sadineni et al. (2011) suggested that if the factors of electricity-savings materials were considered prior to construction, no additional reinvestment of electricity-savings costs would be needed. Regarding indoor air conditioning, Ali and Morsy (2010) compared the electricity-savings potential of 290 W radiant panel heaters and 670 W conventional portable convective heaters, and found that when the outdoor temperature was 10°C, the 290 W radiant panel heaters provided more comfort and saved approximately 56.7% in energy consumption. In addition, Shehabi, Masanet, Price, Horvath, and Nazaroff (2011) studied and tested several large-scale U.S. data center buildings; the results suggested that the local climate, the used airflow management, and proper control sequences were the factors that could be used to potentially save electricity. Their research results also demonstrated that average data center buildings could save 20% to 25% in electricity or energy consumption, and that the server rooms of data centers could save nearly 30% in electricity or energy consumption, amounting to a savings of 1.3 to 1.7 billion kWh of electricity annually.

Although energy-savings architectural space design is an effective energy-savings strategy, other studies have investigated how the billing methods of the household micro-energy generation may influence the energy-savings effect. Darghouth, Barbose, and Wiser (2011) studied 200 households that used two power companies in California as samples and compared the electricity-savings potential of net metering and feed-in tariff. Because most electricity meters in the United States can be measured using two-way measurement (electricity generation and consumption), a net metering policy was implemented to allow users to deduct a portion of the fee from their electricity bills based on the amount of electricity sold. The study conducted by Darghouth et al. (2011) showed that net metering had a better electricity-savings effect than feed-in tariffs, indicating that if electricity-generation income could instantly be reflected in electricity use or electricity expenditure reductions, the users would be more willing to reduce electricity consumption costs.

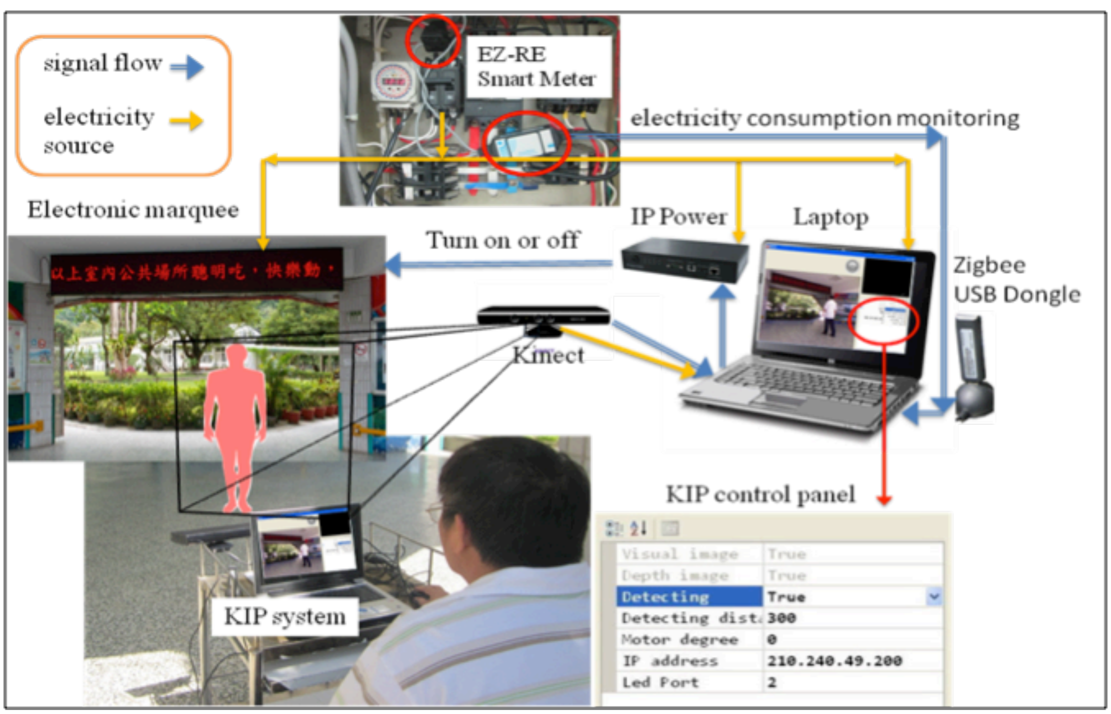
The above mentioned two-way measurements did not provide users access to monitoring and managing their electricity-consumption data. The smart meter is a new digitized electricity-consumption measuring system, which can accurately show electricity usage amounts and return or feedback electricity usage information through the Internet. The research institution In-Stat has estimated that by 2016 smart meters could create a global production value of approximately USD $1.2 billion (Business Wire, 2011). One especially thriving factor for producing this smart meter is its incorporation of the ZigBee wireless sensor network to transmit information. ZigBee is specified as a suite of high-level communication protocols using small, low-power digital radios based on an IEEE 802 standard for personal area networks (Rothe & Girhepunje, 2012). For example, market analysis and forecasts as electric utilities provide a ZigBee wireless sensor smart meter to their electricity customers as a home energy-management tool (Sober, 2011). The Ember Corporation (2010) has developed a type of ZigBee wireless sensor smart meter that could be used as a home and commercial electricity monitoring and management system. This corporation also has promoted its smart meter installation plan in Europe; British Gas was the first company approached and employed by Ember to promote this plan. British Gas anticipated that the installation of wireless smart meters would help its 2 million household users to reduce carbon emissions by providing them with access to monitoring their consumption of either electricity or natural gas. ZigBee's wireless sensor networks have received widespread attention from researchers (Egan, 2005; McCain, 2011; Rothe & Girhepunje 2012). The wireless sensor networks are positioned to provide wireless transmission applications such as controlling air conditioning and lighting for residential and commercial areas, and they are designed specifically to replace the continuous increasing independent remote controls (Egan, 2005). Currently ZigBee has several hundred united or allied industries (ZigBee Alliance, 2012).

In this study, we used a ZigBee wireless energy-management system, named EZ-R Series (included EZ-RE smart meter, ZigBee USB Dongle, and EZ-HD software produced by Joseph Technology Co. Ltd.), as a smart meter for collecting electricity-consumption data. The system was designed by installing a Dongle, a USB tool that conformed to ZigBee Protocol, for the reception of electricity-consumption information from EZ-RE smart meter. The energy-management software, EZ-HD, was installed in a laptop to show real-time electricity-consumption information via the ZigBee USB Dongle when electricity-consumption devices were running. The electricity-consumption data on the EZ-HD included energy consumption rates for one day, one month, cumulative months, or cumulative years (Joseph Technology, 2011). In general, the EZ-R Series could only passively collect electricity-consumption information, and it could not actively help consumers reduce the consumption of electricity without the collocation of other electricity-savings spatial designs. A study conducted by Pan, Chien, Liu, and Chan (2012) indicated that Kinect and IP Power integrated systems could improve the accessibility of electronic devices in schools, for example, it could promote interaction between people and electronic devices with sensors to activate or deactivate devices such as air conditioning and lights. Hence, in this study, we further employed the integrated Kinect and IP Power systems (KIP) to design an electricity-savings context to help us assess the real-time interaction between people and electronic marquees at the school entrance area. The KIP system used in this study consisted of a Kinect, a laptop, an IP Power, an OpenNI, a CL_NUI platform, and an OpenNI SDK; we used C# programming language to write and complete the control program for the KIP system. The KIP system was placed at the front side of electronic marquee, and when a person walked into Kinect's sensing area, the Kinect would transmit the sensor data to IP Power in a laptop Windows operating system and activate the IP Power control program, thereby switching on the power source of the electronic marquee.

The current common sensing methods, such as infrared light emitters and sensors, radio frequency identification, Bluetooth, Zigbee, WiFi, GPS, and depth sensors (such as Microsoft Kinect), all have various configurations and techniques involving detection of proximity (Kumaragurubaran, 2011). But regarding the above sensing methods, the infrared (IR) sensor and depth sensor (Kinect) are the only two methods applied in body sensing without a hand-held device (Hill, 2012). Previous studies (Hu, Jiang, & Zhang, 2008; Ma, 2012; Yamtraipat, Khedari, Hirunlabh, & Kunchornrat, 2006) have shown the effects of using IR sensors for saving electricity. However, IR sensor parts are often interfered by passing dogs, cats, or other animals, causing abnormal activation of the devices (Pan, Lin, & Wu, 2011). In contrast, Kinect can distinguish human presence and has a wider sensor range area than IR. Users also can reconfigure them according to individual needs to develop detection contexts for electronic devices required in different venues (Pan, Tu, & Chien, 2012).

Kinect is a human-body sensing input device by Microsoft for the Xbox 360 video game console and Windows, which enables users to interact with the Xbox 360 without the need for a hand-held controller; it is also a 3D depth sensor that integrates three lenses (Pan, Chien, & Tu, 2012). The IP Power system, launched by the AVIOSYS Corporation, can control the power source switches using the Internet and has four power ports, which can independently manage power sources for four electrical devices (Aviosys International Inc., 2011). In this study, we used the source code drivers released by PrimeSense to write a program that controlled the power source switch of the IP power; the operation would enable the electrical device to actively switch its power on or off based on body-sensing, and thereby achieve energy savings by switching off the electrical device when no one was around to use it.

Figure 1. The KIP System Architecture Used to Save Electricity for the Electronic Marquee



Therefore, the purpose of this study was to install a KIP integrated system for the electronic marquee at the gate of one case study school. The EZ-RE electricity meter, Zigbee USB Dongle, and the electricity monitoring software EZ-HD were employed to assess whether the KIP integrated system indeed has energy-savings potential when applied to an electronic marquee.

Methods

Description of the Test Site

The energy-savings test was conducted at one elementary school located in an aboriginal community at eastern Taiwan. The electronic marquee was placed at the school's front gate, which was the only entrance and exit for the school. The school's principal had suspected that rising electricity costs were due to the placement of this electronic marquee. Therefore, we proposed this KIP system and installed it at the front side of electronic marquee to assess whether it would help to achieve energy savings.

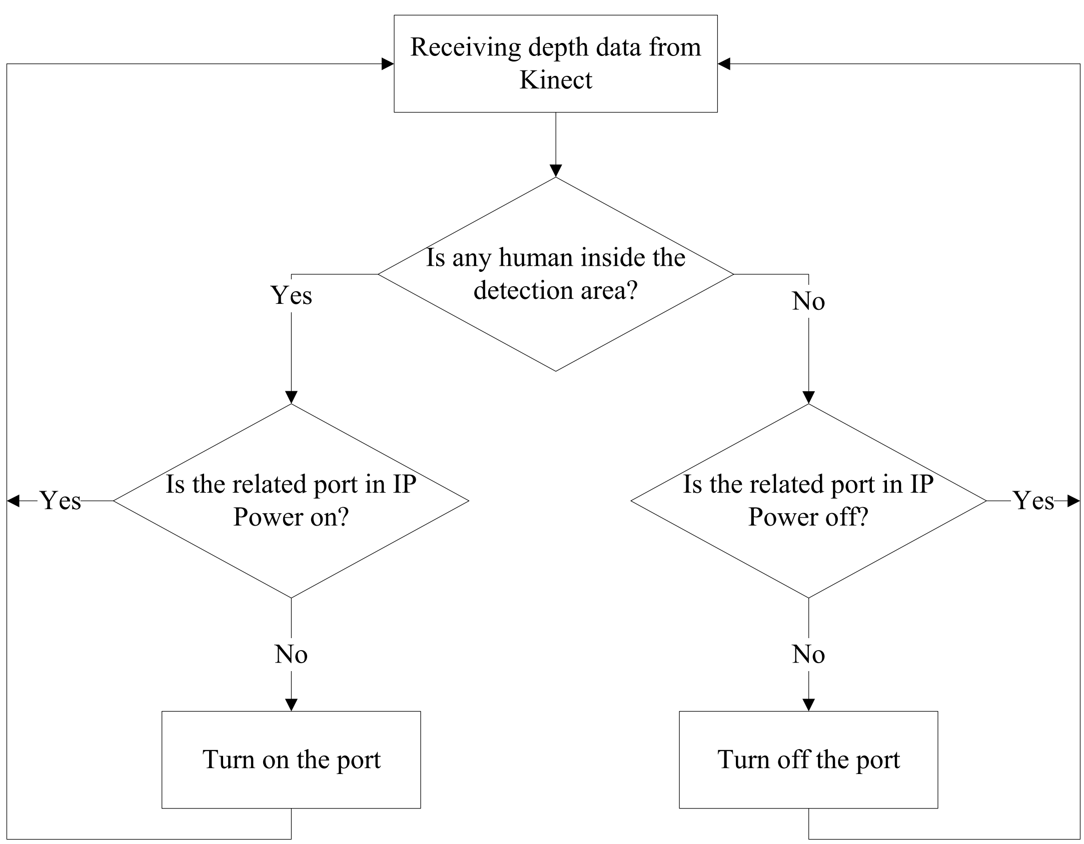
Energy-Savings Architecture of the KIP System

The KIP system architecture used in this study to save energy is shown in Figure 1. The KIP system was placed at the front side of electronic marquee, and when a person walked into the Kinect's sensing area, it would transmit the sensor data to IP Power in a laptop Windows operating system and activate the IP Power control program, thereby switching on the power source of the electronic marquee. Conversely, when no person was present in the Kinect sensing area, the power source of the electronic marquee automatically switched off.

The Software and Hardware of the KIP System

The KIP system used in this study consisted of software and hardware components. The hardware part included the employment of Kinect as depth sensors, a laptop as an operation platform, and an IP Power 9258HP as the remote power switching controller. The software part included the use of OpenNI 5.0.1, CL_NUI

Fig. 2 The information control flow chart of the KIP system



platform 1.0.1210, and OpenNI SDK 1.1.0.41. The OpenNI 5.0.1 was used as the driver to activate Kinect in the Windows operating system; the CL_NUI platform 1.0.1210 was used to activate Kinect's internal motors and enable Kinect to oscillate vertically; the OpenNI SDK 1.1.0.41 was used to write a command program that would translate Kinect's signals into the IP Power's switch functions. In this study, we used C# programming language to write and complete the control program for the KIP system.

The Information Control Flow Chart of the KIP System

Figure 2 shows the information control flow chart of the KIP system. The KIP system used in this study could sense a human presence in the detection area and determine whether the power source for a port on the IP Power should be turned on or off

Using the EZ-RE to Monitor the Electricity Consumption of the Electronic Marquee

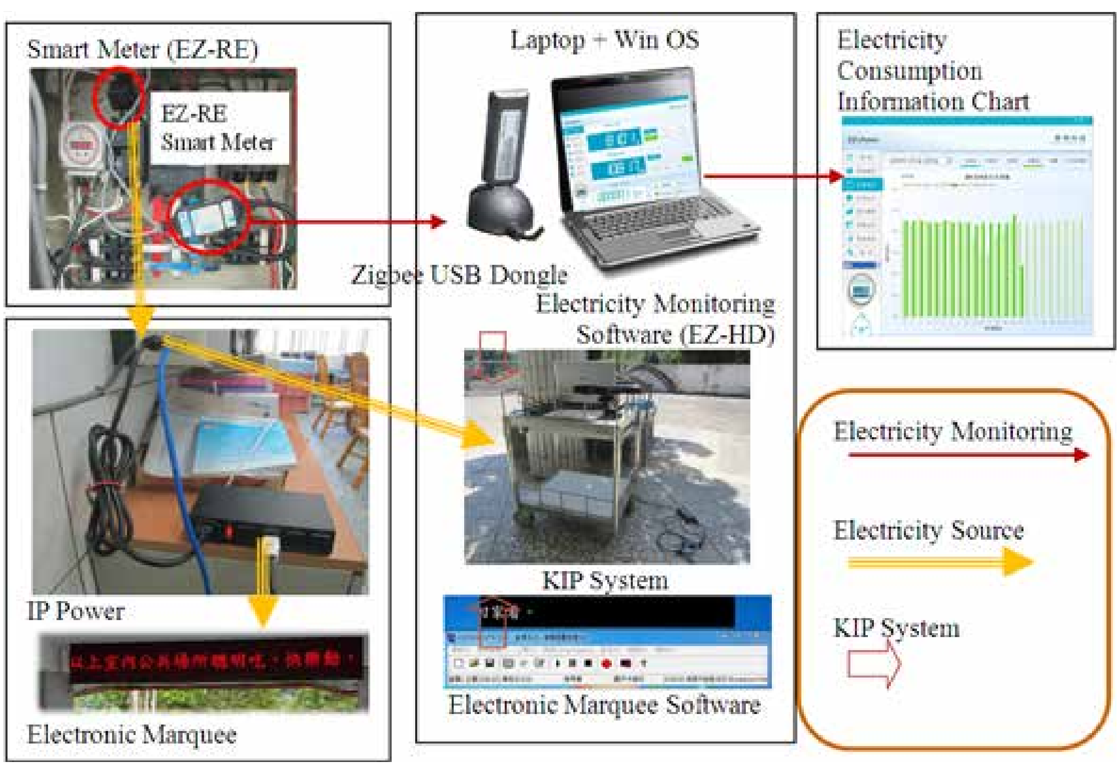
The operational architecture of the EZ-RE smart meter is shown in Figure 3.

The EZ-RE smart meter used in this study provided the functions of measuring current power (W), interval electricity consumption (kWh), and accumulated electricity consumption. An EZ-RE smart meter was used in conjunction with the EZ-HD software and the ZigBee USB Dongle to gather electricity consumption information. The electricity-consumption data gathered from laptop, IP Power, and electronic marquee was measured via EZ-RE smart meter and transmitted via ZigBee USB Dongle to the EZ-HD energy management software. The electricity- consumption data of EZ-HD showed the yearly, monthly, and daily electricity usage, so the data could be converted into statistical information (with or without KIP installed).

The Measurement of Electricity Consumption during Peak and Non-Peak Hours

This study used the electricity consumption of 1.25 kWh for its measurement on May 4, 2012, between 6:30AM and 7:30AM (including the electricity consumption of the accompanying laptop but without KIP system) as the basis for the per-hour electricity consumption rate of the electronic marquee. After we installed the KIP system to the electronic marquee, we continuously measured the electricity consumption rates (kWh) for 10 school months starting on February 2012 at peak hours

Figure 3. The Operational Architecture of the EZ-RE Smart Meter



(6:30AM to 7:30AM) and non-peak hours (9:00AM to 10:00AM). The peak and non-peak hours defined by this study were based on the school routine and the information given by school teachers. In spite of the change of seasons, people passing through the school entrance stayed regular at peak and non-peak hours. Therefore, the researchers simply chose 10 school months to test the electronic marquee with KIP system.

Comparison of the Electronic Marquee's Electricity Consumption Before and After the KIP Installation

Before the KIP system was installed on the electronic marquee, the hourly electricity consumption rate for the electronic marquee (including the electricity consumption of a laptop installed with marquee software) was measured as 1.25 kWh. With the KIP system installation, the electronic marquee power source was activated only when a person was nearby or in the marquee sensor zone, and it would automatically deactivate when no person was nearby or when people left the sensor zone. The electricity-consumption calculation method for the electronic marquee using the KIP is shown in Table 1.

The 10-month average electricity consumption for the electronic marquee installed with the KIP was (B1) kWh at peak hours and (B2) kWh at non-peak hours. We calculated the peak hour electricity saving ratio SR1 (including electricity consumption for the KIP system) using a calculation formula of (1.25-B1)/1.25, and the non-peak hour electricity saving ratio SR2 (including electricity consumption for the KIP system) using a calculation formula of (1.25-B2)/1.25. The energy-savings potential of the KIP system for the campus marquee was assessed by averaging the SR1 and SR2 electricity saving ratios from the two periods.

Results

Measurements taken on May 4, 2012, indicated that the one-hour electricity consumption rate for the continuously activated electronic marquee (including the accompanying laptop) was 1.25 kWh. After the installation of the KIP system, the electricity consumption rates of peak and non-peak hour periods for 10 continuous school months (between February 2012, and January 2013, are shown in Table 2.

The average peak hour electricity consumption rate was 1.09 kWh, the average

Table 1. Comparison Design on Electricity-Saving Effects of KIP System

Time / Electricity Consumption Category	Peak Hours 6:30-7:30	Non-peak Hours 9:00-10:00
One hour of electricity consumption for the electronic marquee (including a laptop)	1.25 kWh (A)	1.25 kWh (A)
One hour average electricity consumption for the electronic marquee with KIP installed (10 month average)	1.09 kWh (B1)	0.85 kWh (B2)
Electricity saving ratio after KIP installation	SR1= (A-B1) / A	SR2 = (A-B2) / A
Average electricity saving ratio after KIP installation	(SR1+SR2) / 2	

Table 2. The Average and Difference of Electricity Consumption Rates for Two Periods of Electronic Marquee with KIP, or Before and After KIP System Installed

Time / Testing Month	Peak Hours 6:30-7:30	Non-peak Hours 9:00-10:00	Average Electricity Consumption (kWh)
2012/2	1.14	0.83	0.99
2012/3	1.03	0.86	0.95
2012/4	1.16	0.91	1.04
2012/5	1.02	0.72	0.87
2012/6	1.17	0.88	1.03
2012/9	1.08	0.95	1.02
2012/10	1.02	0.74	0.88
2012/11	1.15	0.97	1.06
2012/12	1.06	0.86	0.96
2013/1	1.04	0.75	0.90
Mean (10-month)	1.09	0.85	0.97
SD (10-month)	0.06	0.09	0.07

Note: 1. Peak Hours vs. Non-peak Hours, ** $p = .000$ ($t = 11.77$, $\alpha = .01$, $df = 9$, $SD = .065$); 2. Before vs. after KIP system installed, ** $p = .000$ ($t = 12.81$, $\alpha = .01$, $df = 9$, $SD = .069$)

non-peak hour electricity consumption rate was 0.85 kWh, and the average electricity consumption rate for peak and non-peak hours was 0.97 kWh. Based on above results, a paired t-test analysis was conducted and found: 1). the difference between peak hour and non-peak hour of Electronic Marquee with KIP was statistically significant ($t = 11.77$, $\alpha = .01$, ** $p = .000$); 2). The use of before and after Electronic Marquee with KIP system also showed a statistically significant difference ($t = 12.81$, $\alpha = .01$, ** $p = .000$). As shown in Table 2, the electricity-consumption rate after the KIP system installation was significantly lower than the electricity consumption rate prior to its installation when the marquee was left on continuously.

Table 3 shows that the one-hour electricity consumption rate for the original electronic marquee system was 1.25kWh. After the installation of the KIP system, the electronic marquee was activated only during human presence, and the average peak hour electricity-consumption rate was 1.09 kWh, providing an average electricity savings rate of 12.8%; the average non-peak hour electricity consumption rate was 0.85 kWh, providing an average electricity-savings rate of 32.0%; the average hourly electricity-consumption rate was 0.97 kWh, providing an average electricity-savings rate of 22.4%.

The above-mentioned results indicate that the KIP system can significantly reduce the electricity consumption of the electronic marquee. Therefore, we suggest that the KIP system can help to achieve the potential for energy savings for an electronic marquee.

Discussion

The intelligent building automation technologies were expected to grow 8.20% during 2010-2015, and there is also expected to be an increase in personalized control of lighting, temperature, ventilation, and other aspects of the interior environment to enhance the productivity of knowledge workers (MarketsandMarkets, 2011). When the issue of saving energy is concerned, electronic devices and facilities, such as lights, air conditioning units, and electronic marquees should only be active during human presence. However, because these devices are not equipped with human-detection devices,

Table 3. The Energy-Saving Effects of the KIP System on the Electronic Marquee

Electricity Consumption Category \ Time	Peak Hour 6:30-7:30	Non-peak Hour 9:00-10:00
One hour of electricity consumption for the electronic marquee (including the used for marquee titles)	1.25 kWh	1.25 kWh
One hour of average electricity consumption for the electronic marquee after KIP installation (10 month average)	1.09 kWh	0.85 kWh
Electricity saving ratio after KIP installation	12.8%	32.0%
Average electricity saving ratio after KIP installation	22.4%	

they are often active when no one is present, and therefore result in an unnecessary waste of energy. Therefore, the KIP system can be expanded to use with other electrical devices that should only be active when humans are present. Taiwan's school system has approximately 200 school days annually. If we multiply 200 school days by 24 hours a day (The marquee is generally on 24 hours per day in Taiwan's schools) and approximately 0.28 kWh of electricity savings per hour (1.25 – 0.97) and thereafter multiply this number by the basic electricity fee of at least NTD $3.00 per 1 kWh, it comes out that the KIP installed electronic marquee will save approximately NTD $4032 for a school year, or USD $137 The calculation formula is as follows:

$$(200 \text{ days} \times 24 \text{ hr} \times 0.28 \text{ kWh} \times \text{NT\$ } 3) \div \text{Exchange rate } 29.5 \fallingdotseq \text{US\$ } 137$$

$$(\text{Kinect US\$ } 220 + \text{IP Power US\$ } 150) \div \text{US\$ } 137 \fallingdotseq 2.7 \text{ Semester Years}$$

The KIP system can save the school at least USD $137 in electricity fees for a school year, excluding non-school days. Considering the KIP system investment costs of Kinect at approximately USD $220 and IP Power at approximately USD $150, it is estimated that the investment costs for the KIP system can be recovered in approximately 2.7 school years. A study by Hittinger, Mullins, and Azevedo (2012) indicated that the U.S. electricity consumption for video games has continually increased and it would increase by 50% between 2007 and 2010. Such an increase in electricity consumption is primarily caused by users' habit of not turning off gaming consoles when they stopped playing. The KIP system developed by this study is ideal to resolve this problem, and we suggest that the gaming industry could add an automatic shutdown design. As long as the users plug the gaming console into the KIP system, the console power source can automatically be activated or deactivated, depending on human presence in the vicinity of the game console.

According to the test result of this study, we also find that the amount of electricity saved by the KIP system is affected by two factors: the basic electricity- consumption rate of the electronic equipment and the amount of human presence. Regarding the basic electricity-consumption rate factor, the installation of the KIP system can save 22.4% in electricity consumption, but because the electricity consumption rate (in kW) for air conditioners is greater than that of electronic marquees, the KIP system can save more electricity (in kW) for air conditioners than it can for electronic marquees. In addition, in terms of human presence, if an electronic marquee is installed at a smaller school, it would have less human presence because of a small number of students; thus, the energy-savings potential will be greater compared to an electronic marquee installed at a larger school.

Based on the above test result and evaluation, we suggest that it is feasible to apply the KIP system in various building spaces and environments, such as school classrooms or libraries, automatic lighting devices, televisions, air conditioners, or energy-saving design for building security-monitoring systems.

Conclusions

Electronic marquees generally stay on and waste energy, even when nobody walks past them or is present to read them. In this study, the KIP system was installed to an electronic marquee system and used EZ-HD electricity monitoring software to test whether the KIP system would have the potential to save energy. We measured the electricity consumption rates at the case study school for 10 continuous months. It was found that the electronic marquee system in its original continuously active state consumed (including the laptop that runs the marquee title software) 1.25 kWh of electricity per hour, and that the average hourly electricity consumption rate for the marquee system with the KIP system installed was 0.97 kWh. The above result showed an average electricity savings rate of 22.4%, and indicated that the KIP system would help to reduce the electricity consumption of the electronic marquee.

Compared to the IR sensor parts used to automate, activate, and deactivate electronic device power sources in the past, we find that the advantages of the KIP system include: 1). It can detect/distinguish human presence and so it will not activate power sources when animals (e.g., cats and dogs) or other moving objects pass by; 2). It has a wider detection range and so it can be reconfigured according to the individual needs when energy saving is concerned. The KIP system provides users with an avenue to save electricity, so we suggest that it is feasible to apply the KIP system in various building spaces and environments, such as school classrooms or libraries, automatic lighting devices, televisions, air conditioners, or energy-savings building design.

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References

Ali, A. H. H., & Morsy, M. G. (2010). Energy efficiency and indoor thermal perception: A comparative study between radiant panel and portable convective heaters. *Energy Efficiency, 3*(4), 283-301. doi: 10.1007/s12053-010-9077-3

Aviosys International Inc. (2011). *Main features of IP Power* 9258. Retrieved from http://www.aviosys.com/ipenergy.html.

Business Wire (Aug 31, 2011). *Research and markets: Worldwide smart meter revenue to surpass US$12 billion in 2016, ZigBee the early technology leader*. Retrieved from http://www.researchandmarkets.com/research/266c1e/getting_smart_on_w.

Darghouth, N. R., Barbose, G., & Wiser, R. (2011). The impact of rate design and net metering on the bill savings from distributed PV for residential customers in California. *Energy Policy, 39*(9), 5243-5295.

Egan, D. (2005). The emergence of ZigBee in building automation and industrial control. *Computing & Control Engineering Journal, 16*(2), 14-19.

Ember Corporation (2010). Ember emerges as a European Zigbee energy house. *Networks Update, 22*(10), 6-8.

Harvey, L. D. D. (2009). Reducing energy use in the buildings sector: Measures, costs, and examples. *Energy Efficiency, 2*(2), 139-163.

Hill, A. (2012, October 21). *What is an infrared sensor?* Retrieved from http://www.wisegeek.com/what-is-an-infrared-sensor.htm.

Hittinger, E., Mullins, K. A., & Azevedo, I. L. (2012). Electricity consumption and energy savings potential of video game consoles in the United States. *Energy Efficiency*, doi: 10.1007/s12053-012-9152-z

Hu, Y., Jiang, Y., & Zhang, C. (2008). Energy saving control device based on double element pyroelectric infrared sensor. In proceeding of 2008 *Control Conference* (pp. 275-279). July 16-18, 2008, Kunming, China.

Joseph Technology (2011). *Wireless energy meter: EZ-R series*. Retrieved from http://www.joseph-tech.com.tw/products/products_ez_r.htm.

Kumaragurubaran, V. (2011). *Sensing, actuating and processing in the built environment: A beginners guide to physical computing tools*. Retrieved from http://quicksilver.be.washington.edu/courses/arch498cre/2.Readings/1.PDFs/Beginners%20Guide%20to%20Physical%20Computing.pdf.

Ma, Y. (2012). The design and application of intelligent electrical outlet for campus's electricity saving and emission reduction. *Journal of Computers, 7*(7), 1696-1703.

MarketsandMarkets (2011, March). *Global intelligent building automation technologies: Systems services and information Technology market size and forecasts* (2010-2015). Retrieved from http://www.marketsandmarkets.com/Market-Reports/building-technology-346.html.

McCain, D. (2011, June 1). Enabling Zigbee's smart energy 2.0 with advanced wireless modules. *Electronic Component News, 55*, S6-S8.

Moradi, M., Ghaisari, J., Askari, J., & Gorji, M. (2011, May). A new method for detection of a distributed event in wireless sensor networks. In H. S. Zadeh (Chair), *2011 19th Iranian Conference on Electrical Engineering (ICEE)*. Symposium conducted at the meeting of IEEE. Tehran, Iran.

Pan, W.-F., Chien, M.-Y., Liu, C.-C., & Chan, K.-H. (2012). Feasibility analysis of improving the accessibility and security of nano-labs via Kinect. *International Proceedings of Computer Science and Information Technology, 24*, 138-141.

Pan, W.-F., Chien, M.-Y., & Tu, S.-C. (2012, September). The feasibility assessment of using a Kinect-Tablet Integrated System to improve electric wheelchair reversing safety. *Industrial Technology and Management*, *49*, 121-125.

Pan, W.-F., Lin, H.-F., & Wu, M.-Y. (2011, July). Using Kinect to create active-learning situations for nanotechnology labs/classrooms. In Chin-Chen Chang (Ed.), *2011 3rd International Conference on Education Technology and Computer* (pp. 54-56). Singapore: IACSIT press.

Pan, W.-F., Tu, S.-C., & Chien, M.-Y. (2012). Feasibility analysis of improving on-campus learning paths via a depth sensor. *Interactive Learning Environments, iFirst*, 1-24. doi: 10.1080/10494820.2012.682585

Rothe, S. B., & Girhepunje, V. G. (2012). Design and implementation of real time wireless biomedical system based on ZigBee-GSM interactive module. *International Journal of Engineering Research and Applications, 2*(5), 1894-1899.

Sadineni, S. B., Madala, S., & Boehm, R. F. (2011). Passive building energy savings: A review of building envelope components. *Renewable & Sustainable Energy Reviews, 15*(8), 3617-3631.

Shehabi, A., Masanet, E., Price, H., Horvath, A., & Nazaroff, W. W. (2011). Data center design and location: Consequences for electricity use and greenhouse-gas emissions. *Building & Environment, 46*(5), 990-998.

Sober, J. (2011. October 6). *Home energy management*. Retrieved from http://www.acadtest.com/news/131795818315593200-home_energy_management.html.

Yamtraipat, N., Khedari, J., Hirunlabh, J., & Kunchornrat, J. (2006). Assessment of Thailand indoor set-point impact on energy consumption and environment. *Energy Policy, 34*(7), 765-770.

ZigBee Alliance (2012). *About: Our members*. Retrieved from http://www.zigbee.org/About/OurMembers.aspx.

The Cognitive Processes and Strategies of an Expert and Novice in the Design of a Wireless Radio Frequency Network

By Matthew Lammi and Timothy Thornton

ABSTRACT

The purpose of this study was to understand the cognitive processes and procedures employed by an expert and a novice engineer in a realistic radio frequency (RF) systems engineering design challenge by using verbal protocol analysis (VPA). The engineering design challenge encompassed engineering, political, and social constraints. The audio data were then transcribed, segmented, and coded for analysis. The processes and strategies of the expert and novice were juxtaposed for analysis. The expert and novice shared some similarities in their cognitive processes and strategies. However, the expert's domain knowledge and experience was vastly distinct from that of the novice.

Keywords: Engineering design, Systems Design, Design Cognition, Expert- Novice engineer, Engineering and technology education

Introduction

Technological and engineering literacy are critical components of a prosperous society. One dimension of both technological and engineering literacy can be defined as ". . . a way of thinking and acting" (Pearson & Young, 2002, p. 3). Cognitive science addresses ways of thinking as a window to the human mind, shedding light on thought processes and how the mind is structured (Adams, Turns, & Atman, 2003). Because technology and engineering are better understood within the domain of cognition, the further the promulgation of a technologically and engineering literate society. One way to study cognitive processes and strategies is through verbal protocol analysis (Kruger & Cross, 2001).

Engineering is a topic of interest not only limited to the postsecondary training of engineers, but it is also found in the K-12 settings as an educational discipline rich in innovation, problem solving, and higher order thinking skills (Brophy, Klein, Portsmore, & Rogers, 2008). Although engineering literacy is becoming a part of the American educational landscape, there is much to be understood about what engineering literacy is and how to teach it to nonengineering K-12 students. One aspect of engineering literacy is putting engineering habits into thought and action. To better understand these habits, one can employ an expert/novice perspective, where the expert is an engineer and the novice is the presumed student. This perspective describes the point where a student currently is (novice) and where that student could be (expert). The aim of this study was to further the knowledge base of engineering cognition by describing the cognitive processes and strategies of both an expert and a novice in the design of a wireless communications system.

The research questions for this study were:

- What cognitive processes and strategies are used by an expert and a novice in engineering design?
- How do the expert's and the novice's cognitive processes and strategies compare?

Research Literature

This study is based on the foundation of cognitive science as it pertains to engineering and technology education (Brown, 2001). Engineers and technologists are given the task to solve problems, both in the classroom and in practice. Design is a category within problem solving that is cognitively intensive (Jonassen, 2000). Cognition is more than simply to know something; it stems from the Latin word cognoscere, meaning to become acquainted with (Cognition, 2013). To become intimately acquainted with a particular field of practice, one has to acquire thorough knowledge and develop intricate associations. This knowledge and these associations are represented in cognitive science by complex arrays of networks known as schema (Brown, 2001). One of the goals of engineering and technology education is to expose the student to, and hopefully move the student closer to, the skills and thinking of an expert in the field. By observing and analyzing cognition, research may reveal further insights into how experts and novices approach and strategize engineering and technology design. These insights might then aid in engineering curriculum and practices.

Engineering Design

The pervading concept of design is interwoven throughout engineering processes and culture (Burghardt & Hacker, 2004). Design is a nebulous process that may be perceived from either a scientific or an artistic viewpoint (Cross, 2001). Design is dynamic and iterative; therefore, it is not easily represented by simple linear models (Mawson, 2003). Design typically commences with defining and formulating the problem (Cross, 2004). Formulating the problem includes the gathering of pertinent data, delineating the overall goal, and creating an initial plan or "next steps."

Engineering design is more than the manipulation of numbers and the solving of scientific equations. The processes employed in engineering design encompass a broad variety of topics and fields of study. Bucciarelli (1988), an ethnographer, described engineering as a social process. The National Academy of Engineering (2004, 2005) clearly stated that engineering education was lacking if it did not include the global perspective in engineering design such as social, political, and environmental issues. The global perspective in engineering is part of systems engineering. Systems engineering involves viewing design from the whole-systems level rather than from an isolated modular perspective.

Jonassen (2000) placed design in its own problem type in his taxonomy of problem solving. Design is not only listed as complex and ill-structured, but it also requires higher order problem-solving skills. Engineering design typically entails resolving the designer's goal and the criteria set forth by clients or other external parties (Cross, 2002). Very often the external criteria are associated with resources, such as capital or time. Jonassen and Tessmer (1996) further asserted that as a problem type, design skills are influenced by domain knowledge, cognitive skills, and affective traits. This has been supported by Ericsson (2001), who stated that focus and commitment are also factors in expertise.

Because design is an important aspect of both engineering and technology, it has been the focus of numerous studies involving engineering cognition (Atman & Bursic, 1998; Atman, Kilgore, & McKenna, 2008; Cross, 2002; Ericsson & Simon, 1993; Jonassen, 2000; Lammi & Branoff, 2012). These studies used verbal protocol analysis (VPA), or a variation of this analysis, as a major component in gathering data. If VPA is used, the participants verbalize their thoughts out loud while engaged in a task or while solving problems. The participants typically engage in a hypothetical engineering problem or challenge in order to stimulate increased cognitive activity. The VPA is performed in a room where there are few distractions to help the participant maintain mental focus. The participant is also accompanied by a researcher or assistant who records the verbalization with either an audio or video recorder. Although Hayes (1989) conceded that verbal protocols are typically incomplete, he also claimed that under controlled conditions there is no evidence that verbal protocols distort or interfere with a participant's thinking while that participant is engaged in a task.

Expert versus Novice

Students and experts vary according to their ability in engineering design. These differences of engineering design cognition are often analyzed against the expert and novice continuum (Atman et al., 2008; Cross, 2002; Lawson & Dorst, 2005). The novice is limited by experience and knowledge, resulting in a partial and simple schema. The expert has a vast depth of experience and focused practice within a domain, resulting in deep and rich schemata (Cross, 2004). However, experience and knowledge alone do not ensure expertise. The manner in which the experience and knowledge is ordered and interrelated has a great impact on expertise.

An expert is able to recognize large amounts of information, or chunks (Egan & Schwartz, 1979). From these chunks, an expert can recognize what information is relevant to the issue at hand. This enables the expert to quickly and efficiently wade through data and facts with fast retrieval from her/his memory or schemata. This process may be compared to the routing of data packets in a computer network.

The switches are constantly "learning" new and efficient pathways to connect data from one end user to another. The more complete and expanse the connections, the quicker the routing of the data packets. As more equipment and nodes are added to the network, the possibility of a more efficient pathway is introduced. It is evident that adding more nodes to the network alone does not increase efficiency. Rather, it is the deliberate and continual attempts to reroute by the switching equipment that increases efficiency. Hence, when new information or experience is added to the human mind, it is only useful if a purposeful association is made. This deliberate and focused effort was explained by Ericsson (2001) as the primary difference between experts and those who are only proficient in their domains. However, as the solution space evolves and elucidates further constraints, the expert returns to and references, or redefines, the problem space iteratively until the design is implemented, tested, and concluded. These attributes can be combined together to highlight the "know how" that is often demonstrated by an expert. The literature in engineering design cognition has primarily employed verbal protocols analyzed against the expert-novice continuum. Although systems have garnered attention in recent literature (Davis & Sumara, 2006), research regarding cognition in systems engineering design is limited.

Methods

The purpose of this investigation was to understand and compare both an expert's and a novice's cognitive processes and strategies while they are engaged in the design of a systems engineering challenge. There were two participants in this study, an expert and a novice in wireless systems design. A small number of participants was chosen to allow an in-depth analysis of the data. Each of the VPA generated hundreds of data points that were coded and analyzed. The design challenge given to the participants was a hypothetical radio frequency (RF) systems design. The hypothetical setting was chosen to help capture the participants' thinking within the bounds of a VPA.

An RF network is a system of cellular phone towers and accompanying equipment distributed throughout an area to provide cellular phone service. RF systems designs encompass engineering, political, and social variables and constraints. The design challenge was a simulated open-ended RF engineering problem.

VPA was used in this study to gather participants' cognitive strategies and processes as they performed their tasks. Both were invited to share everything they were thinking during the design challenge. To increase trustworthiness and minimize leading questions during the VPA, both participants were only prodded to verbalize if there was at least a five-second pause in sharing their thoughts. As both were encouraged to share all of their thoughts, the resulting transcription was not always coherent or grammatically correct. The VPA was followed immediately by an interview to clarify ambiguities that emerged during the challenge. Additionally, the researcher annotated observations during the challenge, and a design artifact was collected and analyzed. Following the design activity, the audio data were transcribed, categorized, and coded for analysis (Glesne, 2006).

Participants

The sample for this study included two participants drawn from the opposite ends of the expertise continuum in the domain of RF engineering system design. As such, they were selected regarding their skill set within RF engineering system design. Although RF systems engineering is not typically taught at U.S. universities, the coursework in electrical or electronic engineering generally serves as a basic foundation. Additionally, an RF engineer must also have a solid understanding of wave propagation theory in addition to digital communications. To gain proficiency in RF systems design, the engineer must grasp the societal and political impacts while working collaboratively across a wide array of teams (ranging from construction crews to executive management). Expertise in RF engineering is generally obtained through extensive practice in industry because of the frequent complex human interactions that must be balanced with sound engineering design.

An expert RF engineer is not only the most senior engineer among peers, but this person often consults other engineers nationally and internationally. Even within the domain of RF engineering, there are subdomains where one may achieve further expertise: design, optimization, and spectrum allocation. The expert for this study, Robert (pseudonym), had over thirteen years of RF systems engineering design experience working for a major cellular provider in various positions (ranging from manager to internal consultant). This expert received a bachelor's degree in electrical engineering and continued his education through self-learning and corporate training.

The other participant, Gary, was a novice and at the other end of the spectrum of RF systems engineering. He was a professor in electronic engineering technology and had taught electronics at the postsecondary level for more than 35 years. Although this participant was a novice in RF systems engineering design, he had a breadth of skills in pedagogy and undergraduate electronics. He was chosen as the novice because of his background in electrical theory and practical experience with electromagnetic wave propagation; however, he did not have any specific training in RF systems engineering design.

Design Challenge

The participants were asked to design a new RF network in an isolated college town as if they were engineering design consultants. This challenge took place in a small office; only the participant and a researcher were present. Prior to the VPA, both participants were invited to perform a warm-up activity to prepare them to think out loud. In this warm-up activity, both participants gave a virtual tour of their homes. The participants described in detail the interior of their homes, including the windows, wall colors, and type of wood of the cabinets.

Immediately after the warm-up activity, the participants were given a three- dimensional aerial map overlaid with major and minor transportation thoroughfares to aid in the design, as seen in Figure 1. Each participant was invited to place potential cellular towers on this map. Constraints were placed in the design challenge to create a realistic ill-defined scenario. The constraints were to limit capital expenditures and abide by the zoning to not exceed 60-foot towers, and design cell sites to be hidden or

Figure 1. 3D Aerial Map Used During the Design Challenge

stealth. Additionally, both were made aware of high cellular traffic venues, such as a university with 18,000 students and a fictitious annual wakeboarding event that would draw 10,000 individuals.

A follow-up interview was also conducted immediately following the design challenge. The interview questions included the following: why each participant chose varying cellular sites, why certain methods and strategies were employed, and what they were thinking during prolonged pauses. Additionally, the 3-D map served as an artifact for triangulation with the participant's verbalization and interview responses.

Data Collection and Analysis

The audio from the design challenge was transcribed into a word processor. The transcription was broken into units or segments. The segments consisted of a sentence, unless a separate thought or idea surfaced necessitating further segmenting. The segments were coded into distinct mental processes used in engineering. Various methods have been used in coding verbal protocols (Atman & Bursic, 1998; Kruger & Cross, 2001), in contrast, the coding for this study was done from the perspective of the researcher as themes emerged. Although there are various engineering coding schemes, for purposes of this research, a thematic approach was employed to discover any salient themes that emerged. Existing, well-defined coding schemes could potentially limit the outcomes and findings. Furthermore, RF systems engineering is a phenomena that has not been widely researched, especially through VPA.

The Verbal Protocol Analysis

To help the participants relax and have their minds free from distraction the VPAs took place on Friday afternoons when work was slow. To further minimize distractions, the VPAs took place in a quiet and secluded fluorescent-lit room with little decorations. Each participant and the researcher sat at a huge wood laminate table at the middle of the room while they shared their thoughts on solving the design challenge.

Results

Because both participants had multiple years of experience at the systems level in electronics, they both initially utilized a top-down approach in their design. Such an approach begins with the big picture and then breaks the design into its components. Robert, the expert, initially stated, "Is this for the whole area, or is it . . . ?" Not only did Robert commence with this method, he also designed the system to interact with potential existing systems. Both participants also used an iterative process evaluating and visualizing their design against the various constraints. However, Robert was able to more thoroughly analyze and balance the constraints, such as zoning and leasing. Robert quickly noted, "The zoning limitations listed here as stealth design – hmm. Okay, now these are competing requirements: limiting capital expenditures and stealth."

Both the expert and the novice frequently returned to foundational principles for predictions and site locations. Gary, the novice, was fully aware of his limitations and stated repeatedly that he did not have the experience and knowledge to make an accurate design. At one point Gary stated, "I have a lot of questions, but I am not sure." Conversely, the expert was able to make mental predictions or visualizations of the design and relied heavily on experiential and episodic memory. Robert discussed his experience with universities saying, "The university populations historically have a really high penetration rate for mobiles." Although both participants recognized high cellular traffic areas, Robert knew how to quantify and optimize the design. Robert stated, "We are around 80-85% penetration rate now. So, obviously we are going to want to [get] very good coverage along the interstates and highways to support where people frequently use their mobile phones in travel." One possible explanation for this was that the novice did not recognize the particularly high cellular phone traffic implied by a university or a wakeboarding competition.

Robert's, as an expert, design strategy revealed differences from that of Gary's, as a novice. Robert approached the design from a personal viewpoint, drawing heavily from previous experiences and precedents. The expert made frequent references to his experiences, particularly with respect to capital expenditures. Robert commented on the zoning requirements impacting the capital funds, "Because you have lower antenna heights required by the stealth design, you know there is an elevated cost to build sites." Although the participants were given the same tasks, Robert set about the design from the context and point of view of a consultant. He felt that he had to produce a design that was feasible, both financially and with respect to RF engineering. Robert not only produced design, but he also made statements about how it would be zoned, leased, and constructed. Context is an important factor in problem solving, and it was evident in Robert's responses. From the expert's perspective, Robert spent a considerable amount time managing and justifying his design.

One of the most striking contrasts between the participants was the attention Robert gave to the optimization of capital expenditures. It is noteworthy how quickly he recognized the two rival requirements of reduced costs and stringent zoning restrictions commonly known as stealth. This same theme pervaded his entire design process. Even though Robert made 16 references about costs, Gary mentioned costs only 3 times. Additionally, Robert's design proposed only 7 sites (versus 15 for Gary), substantially reducing the cost of the proposed design. Although Gary recognized financial costs in his design, Robert framed nearly every design aspect within the context of costs. This is not surprising since Gary's career is in academe, and Robert's was exclusively in industry, daily working within budgets.

Another striking difference between the expert and the novice was the amount of knowledge in the domain. Figure 2 is a pair of concept maps that reveal the disparity in knowledge differences. The researchers created the concept maps to visually highlight the differences reported between the responses of the novice and expert. Gary did not have the breadth and depth of knowledge that Robert did. Gary also did not allude to or even mention spectrum considerations.

However, the novice did have a working knowledge of radio frequency electromagnetic wave propagation. Gary did mention zoning, leasing, and capacity, but this could partially be accounted for by the design brief. Although not shown on the concept maps, Robert not only mentioned the different aspects within RF design, he also made many connections and associations between concepts.

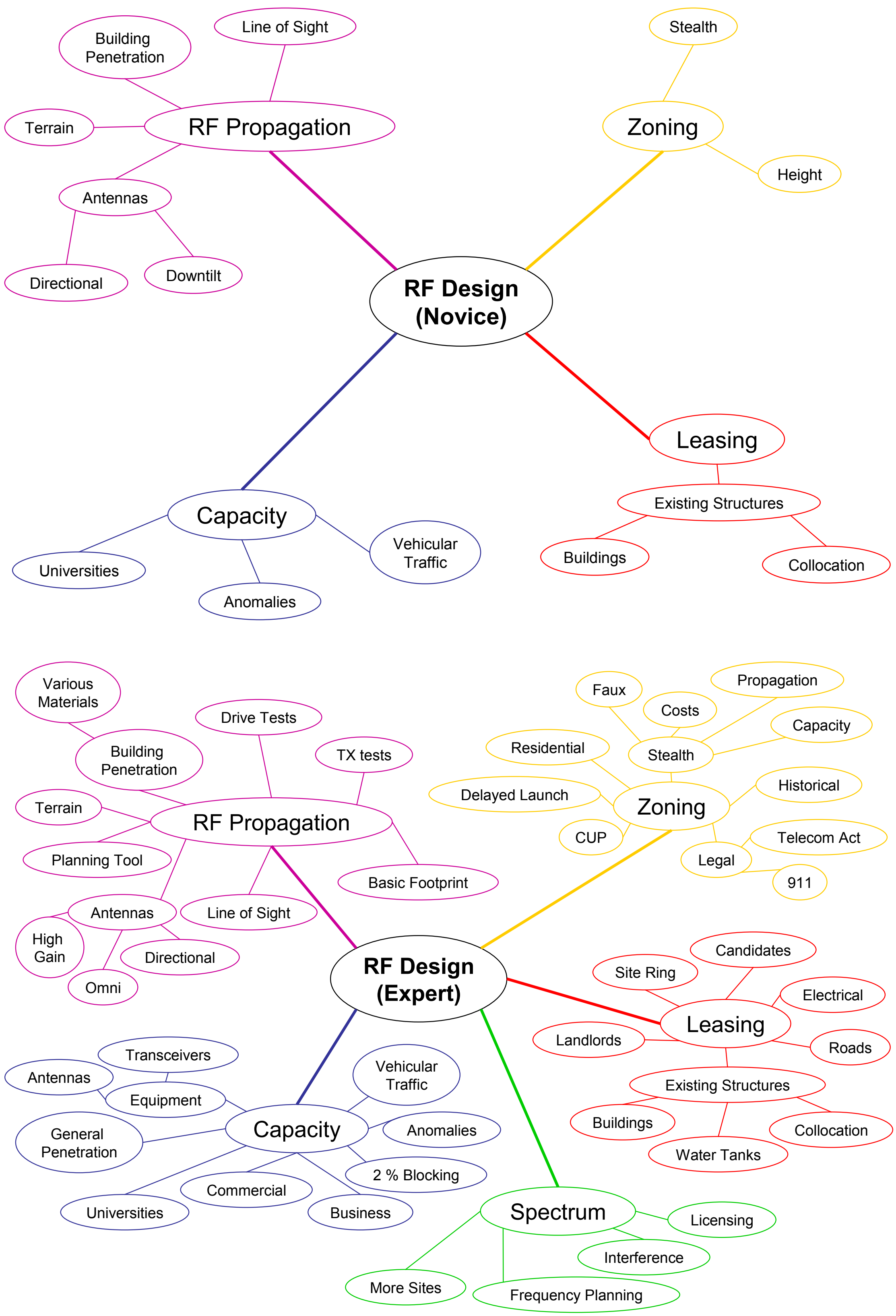
Robert demonstrated the idea of satisficing, or the yielding of an ideal design for one that is only satisfactory. This was expressed as he managed limited capital and accounted for stealth zoning. Robert also made use of techniques unique to his trade, or gambits, to help overcome the stealth requirements. The expert employed water towers, rooftops, and stadium lights as economical alternatives to other costly stealth solutions. Gary was prompted for further analysis and design but he replied, "Experience would probably tell a person more information whether [the system design] is enough or . . . not." Gary was aware that he lacked the relevant experience and domain-specific knowledge to elaborate on his design.

Discussion

From the study we can see how an expert and a novice are alike and how they differ regarding RF engineering system design. The expert exhibited expansive practical knowledge within his domain. The expert also maintained a systems perspective throughout his design by accounting for costs, zoning, and other teams' needs. Furthermore, the expert approached the design challenge from a distinct context. Engineering and technology educators might do well to broadly educate their students to become systems thinkers (National Academy of Engineering, 2005). This systems approach to teaching could include costs, organizational behavior, and political and societal impacts. The design method may be taught, but emphasis should be placed on the idea that there is no universal problem-solving model. Lastly, systems-level engineering could be infused into the curriculum as a top-down approach. This approach emphasizes breadth as well as depth, with the depth being situated in context and not isolated. Presenting the overall concept and then delving into components is an alternative method for reaching varying types of students' learning. This article has presented a few ideas that could be infused to engineering and technology education practice and research that could further increase technological and engineering literacy.

This study included only two participants, one on each end of the expert-novice continuum.

Figure 2. Concept Maps of Gary's (Novice) and Robert's (Expert) RF Designs



Any findings or conclusions were made in light of this limitation. Further research that includes a greater number of participants would be more conclusive. Nonetheless, the results of this study could help be a springboard for other studies and serve as another datum point among other similar studies.

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References

Adams, R. S., Turns, J., & Atman, C. J. (2003). Educating effective engineering designers: The role of reflective practice. *Design Studies, 24*(3), 275-294.

Atman, C. J., & Bursic, K. M. (1998). Verbal protocol analysis as a method to document engineering student design processes. *Journal of Engineering Education, 87*(2), 121-132.

Atman, C. J., Kilgore, D., & McKenna, A. (2008). Characterizing design learning: A mixed-methods s tudy of engineering designers' use of language. *Journal of Engineering Education, 97*(2), 309-326.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education, 97*(3), 369-387.

Brown, D. (2001). Cognitive science concepts and technology teacher education. *Journal of Technology Studies, 27*(1), 33-42.

Bucciarelli, L. L. (1988). An ethnographic perspective on engineering design. *Design Studies, 9*(3), 159-168.

Burghardt, M. D., & Hacker, M. (2004). Informed design: A contemporary approach to design pedagogy as the core process of technology education. *The Technology Teacher, 64*(1), 6-8.

Cognition. In Merriam-Webster's online dictionary. (2013). Retrieved from http://www.merriam-webster.com/dictionary/cognition

Cross, N. (2001). Designerly ways of knowing: Design discipline versus design science. *Design Issues, 17*(3), 49-55. doi:10.1162/074793601750357196

Cross, N. (2002). Creative cognition in design: Processes of exceptional designers. In T. Hewett & T. Kavanagh (Eds.), *Creativity and cognition* (pp. 6-12). New York: ACM Press.

Cross, N. (2004). Expertise in design: An overview. *Design Studies, 25*(5), 427-441.

Davis, B., & Sumara, D. (2006). Complexity and education: Inquiries into learning, teaching, and research. Mahwah, NJ: Erlbaum.

Egan, D., E., & Schwartz, B., J. (1979). Chunking in recall of symbolic drawings. *Memory & Cognition, 7*(2), 149-158.

Ericsson, K. A. (2001). Attaining excellence through deliberate practice: Insights from the study of expert performance. In M. Ferrari (Ed.), *The pursuit of excellence through education* (pp. 4-37). Hillsdale, NJ: Erlbaum.

Ericsson, K. A., & Simon, H. A. (1993). Protocol analysis: *Verbal reports as data*. Cambridge, MA: MIT Press.

Glesne, C. (2006). *Becoming qualitative researchers: An introduction* (3rd ed.). Boston, MA: Pearson, Allyn and Bacon.

Hayes, J. R. (1989). *The complete problem solver* (2nd ed.). Hillsdale, NJ: Erlbaum.

Jonassen, D. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development, 48*(4), 63-85.

Jonassen, D., & Tessmer, M. (1996). An outcomes-based taxonomy for instructional systems design, evaluation, and research. *Training Research Journal, 2*, 11-46.

Kruger, C., & Cross, N. (2001). Modeling cognitive strategies in creative design. In J. S. Gero & M. L. Maher (Eds.), *Computational and cognitive models of creative design V* (pp. 205-226). Sydney: Key Centre of Design, University of Sydney.

Lammi, M., & Branoff, T. (2012). *High school students' habits of mind and action in engineering design*. Paper presented at the ASEE Annual Conference, San Antonio, TX.

Lawson, B., & Dorst, K. (2005). Acquiring design expertise: A first attempt at a model. In J. S. Gero & M. L. Maher (Eds.), *Computational and cognitive models of creative design VI* (pp. 213-229). Sydney, Australia: University of Sydney, Key Centre of Design Computing and Cognition.

Mawson, B. (2003). Beyond 'The design process': An alternative pedagogy for technology education. *International Journal of Technology and Design Education, 13*(2), 117-128.

National Academy of Engineering. (2004). *The engineer of 2020: Visions of engineering in the new century*. Washington, DC: The National Academies Press.

National Academy of Engineering. (2005). *Educating the engineer of 2020: Adapting engineering education to the new century*. Washington, DC: The National Academies Press.

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

The Role of Innovation Education in Student Learning, Economic Development, and University Engagement

By Christy Bozic and Duane Dunlap

Abstract

A model is suggested for the inclusion of innovation education in engineering technology academic programming to enhance student learning, drive business growth, and advance university engagement. Specifically, academic programs that include experiential educational opportunities focused on innovation theory coupled with business and industry partnerships provide a framework for engineering technology students to apply their knowledge benefiting the students, companies, and the regions we serve. These strategic partnerships provide faculty and students with the opportunity to drive economic development through basic research, applied research, workforce education, training, technology transfer, and technical assistance. Successful university-industry collaborations are examined in this paper. Additional research is needed to develop collaboration impact measurements, learning outcomes assessments, and appropriate metrics to quantitatively measure successful collaboration activities.

Key words: Innovation Education, Engineering Technology, Technology Education, Economic Development, University Engagement, Curriculum Development.

Introduction

The need for the integration of innovation curriculum in colleges and universities has been a topic of ongoing discussion at the national level. The Council on Competitiveness, a national organization of CEOs, university presidents, and labor leaders working to ensure American prosperity, held a national innovation initiative summit in 2005 that convened researchers, educators, and business leaders to discuss innovation. From this initiative, the council published a report titled, Innovate America: Thriving in a World of Challenge and Change (Council on Competitiveness, 2005). The report details a national innovation agenda focusing on talent, investment, and infrastructure that allows for innovation growth. The Council on Competitiveness suggests that talent, and more specifically, engineering talent, is our nation's essential innovation asset, although the number of engineers entering the field are not replacing retirees in sufficient numbers (National Science Foundation, 2012). While filling this engineering gap, universities have the opportunity to incorporate relevant innovation-based curricula that are reflective of ill-structured, real-world scenarios for applied engineering and technology students. Colleges and universities are best suited to respond to the challenge of fostering the skills of creative thinking and innovation in their engineering and technology students through engaging and relevant curricula (Sandeen & Hutchinson, 2010).

A university's contribution to local economic development has been long studied and well documented. Historically, universities have viewed traditional research and education as major contributors to economic development (Smith, Drabenstott, & Gibson, 1987). Though discovery and knowledge transfer remain essential cornerstones to university engagement missions, there has been increasing emphasis on expanding the role universities play in innovation and competitiveness to create wealth. The Association of Public and Land-grant Universities' Commission on Innovation, Competitiveness and Economic Prosperity (Milliken, 2012) published a summary of suggestions from business and education leaders for areas of engagement. These suggestions include developing and commercializing technology, increasing industrial collaboration, developing economic policy, developing STEM talent, fostering entrepreneurship, and creating deeper partnerships within P-16 education. Universities are incorporating these strategies to play a key role in building knowledge-based innovation economies. Higher education leadership teams can accomplish this by placing emphasis on creating an entrepreneurial culture to cultivate a fertile ecosystem to promote new business growth. As a result of this culture shift, these universities tend to attract more creative entrepreneurs who have a penchant for innovation and can discover and commercialize new technologies focusing on business attraction.

According to one research-based, Midwest university's economic development working group, "... universities have a huge role in this new economy: helping to support research and innovation... build communities that will meet the needs and expectations, and be attractive, to those with the creative mindsets that are essential for fostering innovation and entrepreneurship" (Deason, 2008, p. 4). This university views its role as a crucial link in the "educational supply chain" (Deason, 2008, p. 4) by creating an innovation culture for faculty, students, and partners.

Universities play a key role in economic development by generating and attracting talent. One of the most critical mechanisms of knowledge transfer from publicly funded universities comes from recently employed skilled graduates in industry (Wolfe, 2005). Research intensive universities produce graduates who enter industry with high levels of research training and applied knowledge. While it is often difficult to quantify these benefits, Bramwell and Wolfe (2008) suggested that students represent the key transfer mechanism to channel scientific research from government-funded universities into industry for the broader purpose of economic development. Engineering technology educators have the opportunity to impart technology-creating skills to students while fostering an innovation mindset (Green, Smith, & Warner, 2012). Providing students with opportunities to apply theoretical knowledge to solve real-world problems allows educators to meet the stated educational mission while contributing to an economic engagement mission.

Applied engineering and technology curricula that incorporate topics such as innovation theory or the innovation process have been shown to better prepare engineers for the global economy (Orr & Eisenstein, 1994; Steiner, 1998). Today's global economy requires engineers to assume the lead role in innovation and idea generation. Although innovation and innovation theory are important topics in engineering technology education, they are not typically taught or embedded within engineering curricula. If innovation and entrepreneurship theory are applied, students can learn to solve ill-structured, real-world business and industry problems (Sandeen & Hutchinson, 2010). Even without an innovation curriculum in engineering and technology degree programs, approximately 60 percent of the CEOs in the Fortune 100 companies have engineering or science degrees (President's Council of Advisors on Science and Technology, 2004).

Innovation and Entrepreneurship Education

At the national innovation summit, the Council of Competitiveness defined innovation as the intersection of invention and insight, leading to the creation of social and economic value (Council on Competitiveness, 2005). Additionally, innovation can be defined as "the process by which technological ideas are generated, developed and transformed into new business products, processes and services that are used to make a profit and establish marketplace advantage"(Mogee, 1993, p. 410). Common to these definitions is the concept of the creation or manipulation of a product or process to be used in a new or different way. During a State of the Union address in 2011, President Obama said, "The first step in winning the future is encouraging American innovation. In America, innovation doesn't just change our lives. It is how we make our living." The president emphasized the role of government and universities to drive innovation through discovery, education, and university engagement. "But because it's not always profitable for companies to invest in basic research, throughout our history, our government has provided cutting-edge scientists and inventors with the support that they need" (The White House Office of the Press Secretary, 2011). Additionally, President Obama underscored the need for further investment in university research and development, challenging educators to focus on education initiatives that promote innovative ideas. To meet this need, universities and colleges are partnering with government, business, and industry by offering educational programs that promote innovation education. Even though these academic programs often contain the word innovation in their title, much of the curriculum is focused on subjects that could be encompassed under the umbrella of entrepreneurship. Entrepreneurship and innovation are often combined into a curriculum and treated as the same theory or subject. Innovation and entrepreneurship are really quite different in both theory and practice. Innovation and entrepreneurship can be viewed as a continuum with innovation as an input in the form of invention and/or product and process development. As a consequence or outcome of this innovation, new businesses or existing business growth is recognized as entrepreneurship (Duval-Couetil & Dryrenfurth, 2012). Many of terms used in the definitions of entrepreneurship concentrate on business concepts such as market trends, leadership, and new business ventures. Terms like these are markedly different than the terms previously mentioned in the definition of innovation. Drucker framed the theories of entrepreneurship and innovation as complementary, but with distinct differences. Innovation is described as a function of entrepreneurship, whether in an existing business or a new venture. When describing entrepreneurship, Drucker stated, "The term, then, refers not to an enterprise's size or age but to a certain kind of activity. At the heart of that activity is innovation: the effort to create purposeful, focused change in an enterprise's economic or social potential" (Drucker, 1998, p. 149).

The study of innovation and innovation theory in engineering and technology is essential for understanding new product and process development, effective decision making, strategic marketing, and leadership excellence. The power of innovative ideas can revolutionize companies and spur new markets. A poll of the top 1,500 international CEOs cited innovative creativity as the top leadership trait for their companies (Dyer, Gregersen, & Christensen, 2009). Figure 1 presents the words or phrases CEOs use to describe the top leadership characteristics for today's economic environment (Berman, 2010).

Given the importance of innovation for new business growth, the theory of innovation can and should be taught to technology students. One such example of innovation theory is that of disruptive innovation. A disruptive innovation creates a new market by applying a different set of values, which ultimately (and unexpectedly) overtakes an existing market (Christensen, 1997). The examination of Netflix's role in the video movie rental market provides a simplified case of disruptive innovation. Netflix is a service that allows customers to stream movie content to any web-based device on demand, thus eliminating the need for customers to drive to video rental stores and choose from in-stock movie title options. Using a customer-focused and low-cost business model, Netflix disrupted the traditional business model of competitors such as Blockbuster. Disruptive innovation theory explains how new companies can utilize "relatively simple, convenient, low-cost innovations to create growth and triumph over

Figure 1: Word cloud with top leadership qualities CEOs cited as most important

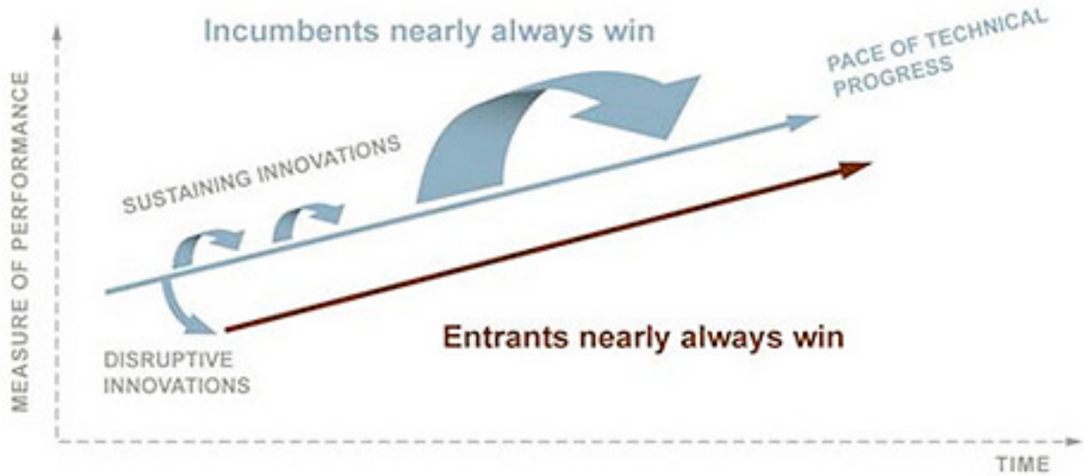

Figure 2: Disruptive innovation model. Reprinted from Clayton Christensen, Disruptive Innovation, by C. Christensen, 2012, Retrieved from www.claytonchristensen.com. Copyright 2012 by Clayton Christensen. Reprinted with permission.

power incumbents" (Christensen, Anthony, & Roth, 2004, p. xv). Additionally, the theory of disruptive innovation suggests that large market leaders or existing companies can maintain market share and market position when an entrant company introduces an innovation that is considered sustaining. A sustaining innovation is one that improves upon existing products or processes (Christensen & Raynor, 2003). When an entrant company introduces a product or service that is disruptive in nature, it changes the entire market because the innovation introduces the new product to an entirely new customer base. Figure 2 provides an illustration of disruptive innovation theory. The lines with arrows illustrate a company's product or process improvement trajectory in a given market. Disruptive innovation theory suggests the incumbent companies in the market will most likely win additional market share on sustaining innovations that marginally improve an existing product as detailed in the top curved arrow. Companies have historically invested in the development of these sustaining innovations charging higher prices to their current customer base with these marginal improvements. It is with these sustaining innovations that companies serve their most sophisticated or demanding customers at the top of any given market to recognize more immediate profits (Christensen, 2012).

By serving top-tier customers, incumbent companies are left open to competition by entrant firms with disruptive innovations to dominate the bottom of the market. These disruptive innovations usually introduce the product family to an entirely new market base who may not be market participants if not for this disruptive product. Innovative disruptions are usually lower in cost, quality, and performance than what the incumbent company produces. Because of the lower cost, slimmer margins, and the perception of inferiority, disruptive innovations are often unattractive to incumbent firms based on well-established performance metrics, yet they are attractive to customers who make purchases based on price over quality. Students who understand the innovation process through the study and application of its theories can make an immediate impact in their careers. Educators can provide students with foundational innovation education to effectively drive or manage innovation to improve productivity and global competitiveness. For example, the partnership between Proctor and Gamble (P&G) and the University of Cincinnati links students with industry to accelerate innovation for P&G's consumers. This collaborative academic-industry partnership developed a modeling and simulation center to advance P&G's product and process development. As a result of this simulation center, P&G has hired 10 students as full-time employees because they were able to "hit the ground running on day one" (UIDP, 2013, p. 2).

Colleges and universities increasingly offer entrepreneurship-focused academic programs, certificates, and minors (Bordogna, Fromm, & Ernst, 1993; Robinson & Haynes, 1991; Seymore, 2001; Standish-Kuon & Rice, 2002). Although there is growth in entrepreneurship education, there is still a need for educational credentials with a specific focus on innovation. One recent study identified only eight undergraduate academic programs focused on innovation. They included three bachelor degree programs, three minors, and two certificate programs (Duval-Couetil & Dryrenfurth, 2012). Additionally, at the graduate level, Dartmouth University offers a Ph.D. program in innovation by combining engineering and business courses with an applied business or industry internship (Dartmouth, 2011). For the innovation core, Dartmouth combines four engineering courses with four business courses to provide graduates with the foundation to build businesses based on technological innovation.

The Need for Research in Innovation Education

Although an innovation curriculum is gaining popularity, published research on effective teaching and learning methods of innovation education for all students, and more specifically, for engineering and technology students is needed. The Ewing Marion Kauffman Foundation (2012) has recognized this need. The Kauffman Foundation's mission is to advance entrepreneurship and improve the education of children and youth through four program areas: (a) entrepreneurship, (b) innovation, (c) education, and (d) research and policy. The Kauffman Foundation supports research and publication specific to innovation and innovation education at all educational levels. As one example, Kauffman sponsored the USC Global Innovation Challenge Summer Program, which supports educators who teach students to develop innovative skills to promote business growth in developing countries. As part of a global collaborative effort, this program teams USC students with students in India to develop innovative solutions to local problems. Through this program, students develop projects and launch companies to meet global challenges. To promote research in innovation, the Kauffman Foundation supports dissertation fellowships and junior faculty fellowships for those graduate students and new faculty who establish a record of scholarship in the area of innovation (Ewing Marion Kauffman Foundation, 2012).

If engineering educators are to meet the need for innovation and economic growth (National Academy of Engineering, 2005) it is important to contextualize innovation and innovation education in terms of engineering and technology curricula. Because research overwhelmingly points to a call to action for applied engineering schools to include innovation and innovative thinking in their curriculums (Bordogna et al., 1993; Gopalakrishnan & Damanpour, 1997; Steiner, 1998), it is important to explore not only the need for innovation theory and practice in engineering and technology education, but also to examine successful and effective instructional methods for this population of students. Steiner (1998) suggested innovative engineering education should focus on management and innovation skills as important hallmarks of success in an engineering career, whereas Bordogna et al. (1993) recommended developing the engineer holistically to encourage innovation and not treating engineering education as a serial process with filters and gates. Whether the innovation curriculum is integrated holistically, programmatically, or as a module within an existing course, the opportunity exists for effective curriculum development and implementation that contains problem-based or work-based education that will benefit both the student and the participating partners. Industry and university collaborations provide the framework for engineering technology faculty to incorporate industry-based projects into their research and instruction.

Although engineering as a practice is highly technical and data driven, the education of engineers and engineering technologists is far from scientific. Engineering educators often rely on intuition, or feeling, rather than gathering data and proving which instructional methods are most effective for engineering students in different learning environments. "Unlike the technical community, wherein data-driven results from one lab have widespread impact on the work of peers, many educational reformers have not incorporated research on learning into their work" (National Academy of Engineering, 2005, p. 26). Additionally, because engineering and technology students learn most effectively in a setting that allows them to apply knowledge actively with projects and case studies (Prince & Felder, 2006), university partnerships with business, industry, nonprofits, and government can provide students with the opportunity to work on real-world projects as part of their innovation education. Industry-based projects encourage students to learn and apply knowledge immediately. This situated cognition allows students to understand abstract concepts and procedures while actively deploying theory (Brown, Collins, & Duguid, 1989) in a controlled workplace setting.

Leveraging University-Industry Partnerships for Innovation Education

Universities can form purposeful and meaningful partnerships with industry for the benefit of students. These collaborative partnerships provide students with a relevance to their academic learning process. For example, colleges can use industry-sponsored senior capstone projects for student teams to solve problems or challenges faced by companies. These projects provide students with the opportunity to apply their knowledge and gain valuable experience,

"... students want relevance in the content of their courses and are interested in learning how to do things that will enable them to be successful as practicing engineers. They are also interested in learning things that will be of value to their prospective employers and will be seen as such on their resumes" (Todd & Magleby, 2005, p. 204). Additionally, these partnerships allow companies to access a pool of potential new engineers without the expense of traditional recruiting activities. Further, it is an opportunity for industry to reach out to academic resources to assist them with product or process challenges. Leaders in industry often seek access to research within academia to which they can quickly apply for a competitive market advantage (Todd & Magleby, 2005; Yamada & Todd, 1997). Building upon the foundation of innovation theory, students can be effective pipelines for innovation for industrial partners. Successful frameworks for university-industry partnerships are ones in which all stakeholders benefit through an open line of communication, collaboration, and a well-defined accountability structure. Although industrial and educational collaborations can be successful in many forms, we suggest these partnerships define and document goals and expectations in the following three areas:

Mutual Benefit

First, an industrial partner must see the benefit of partnering with a university. The most effective partnerships between universities and industry are the ones in which the benefits to both parties are explicitly defined and continually revisited. These partnerships should be formed around mutual needs and market demands where there is value added to both parties as a result of the collaboration (Ryan & Heim, 1997). One example of a successful university-industry partnership is the relationship between DuPont and Penn State. Both partners have a shared interest in total quality management (TQM). DuPont sought to outsource research and development in this area, whereas Penn State viewed this as an opportunity to expand research in this area. Penn State and DuPont collaboratively focused on human resource development, continuing education, and technology transfer through this TQM relationship.

Single Point of Contact

Penn State attributes the success of this relationship to maintaining a single point of contact at each organization to drive measurable results. This two-person team "... has taken on the role of technology liaison between the two institutions, each representing the mission and interests of his respective organization" (Ryan & Heim, 1997, p. 43). From this partnership, Penn State expanded its corporate training programs, refined its academic advising process, and revised its manufacturing engineering program's curriculum to better emphasize the "interdependency of design in a business environment" (Ryan & Heim, 1997, p. 44) to benefit both the student and the company.

Defined Research Area

Industrial partners often fund and engage with university centers or technology incubators for the purpose of cooperative research, knowledge transfer, and technology transfer (Santoro, 2000). These centers are primarily focused on one particular research area, for example, energy, the environment, advanced manufacturing with the sole purpose of driving research and innovation within that focus area. Often, similar companies invest in these centers as a consortium to strengthen research and development as an industry (Geisler, Furino, & Kiresuk, 1990). An example of a university-based research center is Carnegie Mellon University's Center for Iron and Steelmaking Research, which is funded by 15 manufacturers associated with the iron and steel industries. Initially the center was funded by the National Science Foundation in 1985, but it has remained self-supporting primarily through funding from industry. The mission of the center is to conduct basic fundamental research to support the efficient production of iron and steel while educating students for these industries. This is accomplished by connecting both graduate and undergraduate students with industry and company-specific research projects (Fruehan, 2006).

However these partnerships are formed and managed, it is through these collaborative efforts universities play a role in economic development by accelerating organizational learning and building communities of innovation (Carayannis, Alexander, & Ioannidis, 2000). Industry-university partnerships spur discovery, promote application of knowledge, and build a more innovative and talented workforce. Others support this view:

> The key then is to move away from the limited concept of the university as an engine of economic development and begin to view the university as a complicated institutional underpinning of regional and national growth. If nations and regions are really serious about building the capacity to survive and prosper in the knowledge economy and in the era of talent, they will have to do much more than simply enhance the ability of the university to transfer and commercialize technology. (Regional partnerships) will have to act on this infrastructure both inside and surrounding the university in ways that make places more attractive to and conducive to talent. (Branscomb, Kodama, & Florida, 1999, p. 607).

Recommendations

Universities have a unique opportunity to contribute to the economic vitality of the regions they serve via connecting students with industry through work-based educational experiences. Students can serve as a pipeline of innovation by applying theoretical and applied knowledge to solve actual industry challenges. Engineering technology educators teach mechanical/electrical theory along with the application of those theories to students for the purpose of product and process design. Instructors can and should incorporate innovation theory into the technology curricula to spur future technology business growth from graduates.

If educators are to meet the growing demand for engineering and technology talent and cultivate an innovation mindset in graduates, further research is needed to identify effective teaching and learning strategies that include work-based learning and case studies in the classroom. To measure the effectiveness of these programs, appropriate metrics should be developed to accurately report the benefits to not only faculty and staff, but also to the companies and regions served through these collaborations. Additional research is needed to assess the learning styles of engineering technologists with regard to the application of entrepreneurship and innovation education.

Universities should address common roadblocks in university-industry collaborative partnerships. The topics of intellectually property ownership, liability, and memorandum of understanding are often debated, ill-defined, and over-negotiated to the point where it is no longer feasible for these partnerships to exist. Often these partnerships are sought out by either the university or the company to exploit a specific opportunity, which can quickly expire before the time the contracts have been agreed upon. Universities should develop and follow a streamlined process for engagement that allows students, faculty, and administrators to be proactive and nimble regarding the needs of their business partners and the regions they serve.

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References

Berman, S. (2010). *Capitalizing on Complexity*. Report from IBM Business Services. Somers, USA.

Bordogna, J., Fromm, E., & Ernst, E. W. (1993). Engineering education: Innovation through integration. *Journal of Engineering Education*, *82*(1), 3-8.

Bramwell, A., & Wolfe, D. A. (2008). Universities and regional economic development: The entrepreneurial University of Waterloo. *Research Policy*, *37*(8), 1175-1187.

Branscomb, L. M., Kodama, F., & Florida, R. (1999). *Industrializing knowledge*: University-industry linkages in Japan and the United States Retrieved from http://books.google.com/books?hl=en&l=&id=OfrC8kEev1QC&oi=fnd&pg=PR9&dq=Industrializing+knowledge:+Univers ty-industry+linkages+in+Japan+and+the+United+States&ots=6CFvwzMrEu&sig=agawOAcRott dO5j15nx7nkWJ1o

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*(1), 32-42.

Carayannis, E. G., Alexander, J., & Ioannidis, A. (2000). Leveraging knowledge, learning, and innovation in forming strategic government–university–industry (GUI) R&D partnerships in the US, Germany, and France. *Technovation*, *20*(9), 477-488.

Christensen, C. M. (1997). *The innovator's dilemma: When new technologies cause great firms to fail*. Boston, MA: Harvard Business Press.

Christensen, C. M. (2012). Bio, beliefs, ideas in action, key concepts, latest thinking. Retrieved from www.claytonchristensen.com

Christensen, C. M., Anthony, S. D., & Roth, E. A. (2004). Seeing what's next: U*sing the theories of innovation to predict industry change*. Boston, MA: Harvard Business Press.

Christensen, C. M., & Raynor, M. E. (2003). *The innovator's solution: Creating and sustaining successful growth*. Boston, MA: Harvard Business Press.

Council on Competitiveness. (2005). I*nnovate America: Thriving in a world of challenge and change*. Paper presented at the National Innovation Initiative Summit, Washington, DC.

Dartmouth. (2011). Ph.D innovation programs and fellowships. Retrieved from http://engineering.dartmouth.edu/academics/graduate/innovation/

Deason, G. (2008). *Purdue University and economic development: Defining the 21st centry land grant university*. Economic Development Working Group. Purdue Univeristy.

Drucker, P. F. (1998). The discipline of innovation. *Harvard Business Review*, *76*(6), 149-157.

Duval-Couetil, N., & Dryrenfurth, M. (2012). *Teaching students to be technology innovators: Examining approaches and identifying competencies*. Paper presented at the American Society for Engineering Education Annual Conference, San Antonio, TX. http://www.asee.org/public conferences/8/papers/4817/view

Dyer, J. H., Gregersen, H. B., & Christensen, C. M. (2009). The innovator's DNA. *Harvard Business Review*, *87*(12), 61-67.

Ewing Marion Kauffman Foundation. (2012). Ewing Marion Kauffman Foundation. Retrieved from www.kauffman.org

Fruehan, R. J. (2006). Center for iron and steelmaking research, 2012. Retrieved from http://neon.mems.cmu.edu/cisr/about/index.html

Geisler, E., Furino, A., & Kiresuk, T. J. (1990). Factors in the success or failure of industry-university cooperative research centers. *Interfaces*, *20*(6), 99-109.

Gopalakrishnan, S., & Damanpour, F. (1997). A review of innovation research in economics, sociology and technology management. *Omega*, *25*(1), 15-28.

Green, J. V., Smith, J. A., & Warner, J. R. (2012). First year review of the entrepreneurship and innovation program (EIP) at the University of Maryland. *The Journal of Engineering Entrepreneurship*, *3*(1), 8.

Milliken, J. B. (2012). The innovation and competitiveness agenda 2012 - A summary of suggestions from business and education leaders for areas of engagement and focus in innovation and competitiveness: Association of Public and Land-grant Universities, Commission on Innovation, Competitiveness and Economic Prosperity

Mogee, M. E. (1993). Educating innovation managers: Strategic issues for business and higher education. *IEEE Transactions on Engineering Management*, *40*(4), 410-417.

National Academy of Engineering. (2005). *Educating the engineer of 2020: Adapting engineering education to the new century*. Washington, DC: National Academies Press.

National Science Foundation. (2012). *Science and engineering indicators* 2012. (NSB12-01). January 2012: Retrieved from http://www.nsf.gov/statistics/seind12/c3/c3h.htm.

Orr, J. A., & Eisenstein, B. A. (1994). Summary of innovations in electrical engineering curricula. *IEEE Transactions on Education*, *37*(2), 131-135.

President's Council of Advisors on Science and Technology. (2004). *Sustaining the nation's innovation ecosystem: Maintaining the strength of our science and engineering capabilities*. Retrieved from http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-04-sciengcapabilities.pdf.

Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of Engineering Education*, *95*(2), 123.

Robinson, P., & Haynes, M. (1991). Entrepreneurship education in America's major universities. *Entrepreneurship Theory and Practice*, *15*(3), 41-52.

Ryan, J. H., & Heim, A. A. (1997). Promoting economic development through university and industry partnerships. *New Directions for Higher Education*, *1997*(97), 42-50.

Sandeen, C. A., & Hutchinson, S. (2010). Putting creativity and innovation to work: Continuing higher education's role in shifting the educational paradigm. *Continuing Higher Education Review*, *74*, 81-92.

Santoro, M. D. (2000). Success breeds success: The linkage between relationship intensity and tangible outcomes in industry–university collaborative ventures. *The Journal of High Technology Management Research*, *11*(2), 255-273.

Seymore, N. (2001). ERIC Clearinghouse on Entrepreneurship Education, L.A. *Entrepreneurship Education in American Community Colleges and Universities.*

Smith, T. R., Drabenstott, M., & Gibson, L. (1987). The role of universities in economic development. *Economic Review*, *72*(9), 3-21.

Standish-Kuon, T., & Rice, M. P. (2002). Introducing engineering and science students to entrepreneurship: Models and influential factors at six American universities. *Journal of Engineering Education*, *91*(1), 33-40.

Steiner, C. J. (1998). Educating for innovation and management: The engineering educators' dilemma. *IEEE Transactions on Education*, *41*(1), 1-7.

Todd, R. H., & Magleby, S. P. (2005). Elements of a successful capstone course considering the needs of stakeholders. *European Journal of Engineering Education*, *30*(2), 203-214.

UIDP. (2013). Procter & Gamble / University of Cincinnati Simulation Center. *University-Industry Demonstration Partnershp*. Retrieved from http://sites.nationalacademies.org/pga/uidp pga_072996

White House Office of the Press Secretary. (2011). *Remarks by the president in state of union address*. Retrieved from http://www.whitehouse.gov/the-press-office/2011/01/25/remarks-president-state union-address

Wolfe, D. A. (2005). Innovation and research funding: The role of government support. In F. Iacobucci & C. Tuohy (Eds.), *Taking public universities seriously* (pp. 316-340). Toranto, Canada: University of Toronto Press Incorporated.

Yamada, T., & Todd, R. H. (1997). The quest for relevance: Roles for academia and industry in Japan and the US. *Journal of Engineering Education*, *86*, 341-348.

It's a "Clicker," not a Magic Wand: The Effect of a Classroom Response System on Attendance

By Raoul Amstelveen

Abstract

This study employed a rank-based nonparametric test to examine the effectiveness of a Classroom Response System (also known as a "clicker") on attendance. A Mann-Whitney U test revealed that attendance in the clicker class (experimental group) and attendance in the nonclicker class (control group) did not differ significantly. However, a survey of 28 participants in the clicker class showed that learners had positive perceptions of clickers. Two focused group sessions in the clicker class also revealed that learners enjoyed using clickers and that they found the clicker technology engaging, interactive, and entertaining.

Key words: Attendance; Nonattendance; Engagement; Classroom Response System (CRS); Clicker; Introductory Statistics

Introduction

Nonattendance in higher education is not only a local or national problem—it is also a universal problem (Barlow & Fleischer, 2011; Cleary-Holdforth, 2007). Nonattendance is such a complex and pesky issue in higher education that researchers do not agree on the depth or scope of the problem. Some researchers argue that student nonattendance is getting worse and is now trending upward (Massingham & Herrington, 2006), whereas others maintain that it has always been a problem (Rodgers, 2002). At the very least, nonattendance has been a major issue in higher education for the last four decades (Romer, 1993). Even though Romer's findings regarding nonattendance have sparked renewed debate about why students do not attend, to date there have not been any unified conceptual models or attempts to provide generalized theory concerning nonattendance among learners in higher education. This lack of generalized theory makes it more difficult to analyze nonattendance among students in higher education. Also troublesome is that introductory statistics can be an arduous and unpleasant subject for many nonscience majors (Bradley, 2009). When students reluctantly attend, they often appear unmotivated, disengaged, and disinterested in the lectures.

Literature Review

The quality of lectures has been documented as playing an integral role in attendance rates. Not missing lectures could be explained with reference to (a) the enthusiasm of the lecturer, (b) a sufficient level of activity and participation in the course, and (c) a clearly structured classroom (Revell & Wainwright, 2009). For instance, Hunter and Tetley (1999) concluded that students want lectures that are interesting, informative, and difficult to make up. In their study, students who were surveyed cited that the number one reason for not missing lectures was an expectation that the lectures would be interesting. The instructor's personality also appears to have a dramatic effect on whether or not students attended a lecture (Massingham & Herrington, 2006; Revell & Wainwright, 2009; van Schalkwyk, Menkveld, & Ruiters, 2010). According to Massingham and Herrington (2006), instructors who are charismatic, humorous, likeable, and energized are more likely to motivate students to attend lectures. Furthermore, teachers who develop meaningful lessons (Dolnicar, 2005) and focus on themes, concepts, and principles appear to make it more worthwhile for students to attend (Fitzpatrick, Cronin, & Byrne, 2011). Fitzpatrick et al. concluded that the main reason students attend lectures is because of quality teaching that actively engages learners in critical topics. Therefore, students will attend as long as they perceive "value" in attending, and one way to exude value is for teachers to be competent in their instruction (Massingham & Herrington, 2006, p. 84).

Efforts to increase active learning have made Classroom Response Systems (CRS)—also known as "clickers"—popular tools in higher education. Clickers are hand-held electronic devices similar to TV remote controls or mobile cellular phones that allow students to transmit their responses onto a screen where they can be automatically tabulated and summarized by software. The overall class results may then be stored, tallied, graded, and formalized into a bar graph or pie chart for the entire class. Clickers are being increasingly used, and they appear to be the gateway for newer response systems and technologies that utilize mobile devices in higher education. For instance, the company iClicker boasts that its technology is used by more than 1,300 higher education institutions (www.iclicker.com).

In a literature review of 67 studies, Kay and LeSage (2009) supported the claim that attendance does improve in clicker classes, especially when clickers are attached to the final grade. According to Dunham (2009), even using motivational incentives as small as an extra two percent toward a student's final grade encourages attendance among clicker users in introductory statistics courses at the University of British Columbia. Therefore, when clickers are connected with points toward the final grade, class attendance increases (Dunham, 2009; Kay & LeSage, 2009). However, instead of conducting headcounts of the total number of students in class, the majority of research studies that have investigated nonattendance in higher education have been correlational in nature. Moreover, most studies rely on students' perceptions and therefore employ survey techniques (e.g., Gok, 2011; Gupta, 2010; Prather & Brissenden, 2009).

It is also important to note that reviews of the connection between clickers and improved attendance do not always produce positive results. For instance, Laxman (2011) conducted a survey in 12 engineering courses consisting of 640 students and found that about 49% of participants claimed that clickers did not motivate them to attend. Other researchers reported no significant changes in attendance as a result of using clickers (King & Robinson, 2009). Some researchers even argued that clickers actually may be detrimental when used to monitor attendance, because students disliked losing marks for missing classes (Milner-Bolotin, Antimirova, & Petrov, 2010).

Theoretical Framework

The theoretical framework upon which this particular study is based is the worker attendance model. According to Steers and Rhodes (1978), the conceptual attendance model (also known as the pain-avoidance model) posits that attendance is influenced by subjects' motivation to attend and by their ability to attend. Furthermore, motivation to attend is partly dependent on how satisfied the workers are with their job situation, as well as other pressures to attend. This is analogous to the learners' level of satisfaction with their course and the decision to attend or nor not attend (Clark, Gill, Walker, & Whittle, 2011). Allen's (1981) labor-leisure model represents another example in which workers weigh the outcome of labor (attending) versus leisure (not attending). The perceived outcome that outweighs the other will win. This study intends to establish a link between absence theories regarding workers and nonattendance theories for students in higher education.

Hypothesis

This study made the following hypothesis:

H0: There is no difference in the mean ranks (median) attendance rates among learners in introductory statistics classes who use clickers and learners in introductory statistics classes who do not use clickers.

H1: There is a difference in the mean ranks (median) attendance rates among learners in introductory statistics classes who use clickers and learners in introductory statistics classes who do not use clickers.

Methodology

This study employed a nonprobability sampling technique to select two introductory sections taught by the author during the 2012-2013 winter academic term.

iClicker

There are many brands of clicker response systems, such as TurningPoint, iClicker, Hyper-Interactive Teaching Technology, Qwizdom, InterWrite PRS, eInstruction, and Option Technology Interactive. Mobile devices (such as smart phones) are becoming increasingly popular and may become the latest trend in higher education. However, the author chose the iClicker 6.1 version because of its portability, ease of use, and relatively low cost for students. More important, the university at which the study was conducted supports iClickers and has class sets available for instructors who wish to implement CRS into their courses. Therefore, participants in this study did not need to purchase clickers because a class set was available.

Participants

The study was conducted in a small-sized, private, undergraduate university located in South Florida. The sample consisted of 68 learners enrolled in two introductory statistics sections taught by the author during the 2012–2013 winter academic term. Of the 68 participants, 33 learners used clickers (treatment group) and 35 learners did not use clickers (control group). The nonclicker section met on Tuesdays and Thursdays, whereas the clicker class met on Mondays and Wednesdays. Both sections met in the early afternoon. The Monday-Wednesday class was chosen as the treatment group because nonattendance had been higher on those days. Moreover, by choosing the Monday-Wednesday class as the treatment group, the effectiveness that clickers had on attendance could be determined based on statistically significant results (Wood, Burke, Da Silva, & Menz, 2007). The clicker and nonclicker classes were similar in terms of gender, age, class standing, and GPA (see Table 1).

Procedure

Learners in the clicker class used clickers during every scheduled meeting except the first meeting, during examinations, and during the last two lecture meetings. Meanwhile, learners in the nonclicker class did not use clickers at any point during the term. Participation in the nonclicker class was based on the percentage of classes that learners attended. In the clicker

Table 1. Demographics of Participants in Clicker and Nonclicker Classes (N = 68)

Variable	Frequency		Percent	
	Clicker	Nonclicker	Clicker	Nonclicker
Age				
18-19	9	11	27.3	32.4
20-21	12	17	36.4	50.0
22 and older	12	6	36.4	17.6
Total	33	34		
Gender				
Female	16	19	48.5	54.3
Male	17	16	51.5	45.7
Total	33	35		
Class Standing				
Freshman	1	0	3.0	0.0
Sophomore	9	15	27.3	42.9
Junior	11	13	33.3	37.1
Senior	12	7	36.4	20.0
Total	33	35		
Ethnicity				
African-American	7	13	21.2	37.1
Hispanic	9	15	27.3	42.9
White Non-Hispanic	13	6	39.4	17.1
Other	4	1	12.1	2.9
Total	33	35		
Grade Point Average				
0.00 - 2.99	8	13	25.8	43.3
3.00- 4.00	23	17	74.2	56.7
Total	31	30		

class, participation was determined based on the number of clicker points. To eliminate anxiety about clicker scores, learners were allowed to earn one point for correct clicker responses and one-half a point for incorrect responses. Participation in the clicker and nonclicker class course counted 5% toward a student's final grade. A clicker participation grade of 5% was deemed reasonable (e.g., Fitzpatrick et al., 2011; Milner-Bolotin et al., 2010), because this percentage was not so weighty as to impose anxiety about statistics or clicker questions yet it was sufficiently high that students would be likely to take clicker questions seriously. It was also theorized that this strategy would reduce the likelihood of students attending solely for the purpose of earning clicker participation points.

iClicker questions were always predesigned and used in conjunction with a PowerPoint slide. Clicker questions were usually asked toward the end of the lecture, except when students appeared to be tired, bored, or weary from the lecture. At those times, clicker questions were used during the middle of the session. Clicker questions in the middle of the lecture provided a nice change of pace, and they provided students with a break from standard lecture formats. When clicker questions were used in the beginning of the lecture, students who arrived late often lost clicker points. During the focus group sessions, participants mentioned that they were frustrated by clicker questions that were asked at the beginning of the period; they preferred the clicker questions to be asked at the end (or at least at the beginning and the end) of the lecture. During clicker questions, students spoke freely among themselves, clarifying, confirming, and analyzing clicker questions. They sometimes blurted out the answers without giving other students an opportunity to try it out for themselves. However, such actions were allowed because they indicated that students were engaged in the lesson. Each time clicker questions were asked, there was a visible increase in "noise" and enthusiasm, which was encouraged because it seemed that students were learning both individually and cooperatively.

Clicker questions posed in the clicker class were taken from the current textbook used in the institution, from other textbooks, or from other researchers. For example, Figure 1 illustrates a modified clicker question from

Figure 1. iClicker modified question

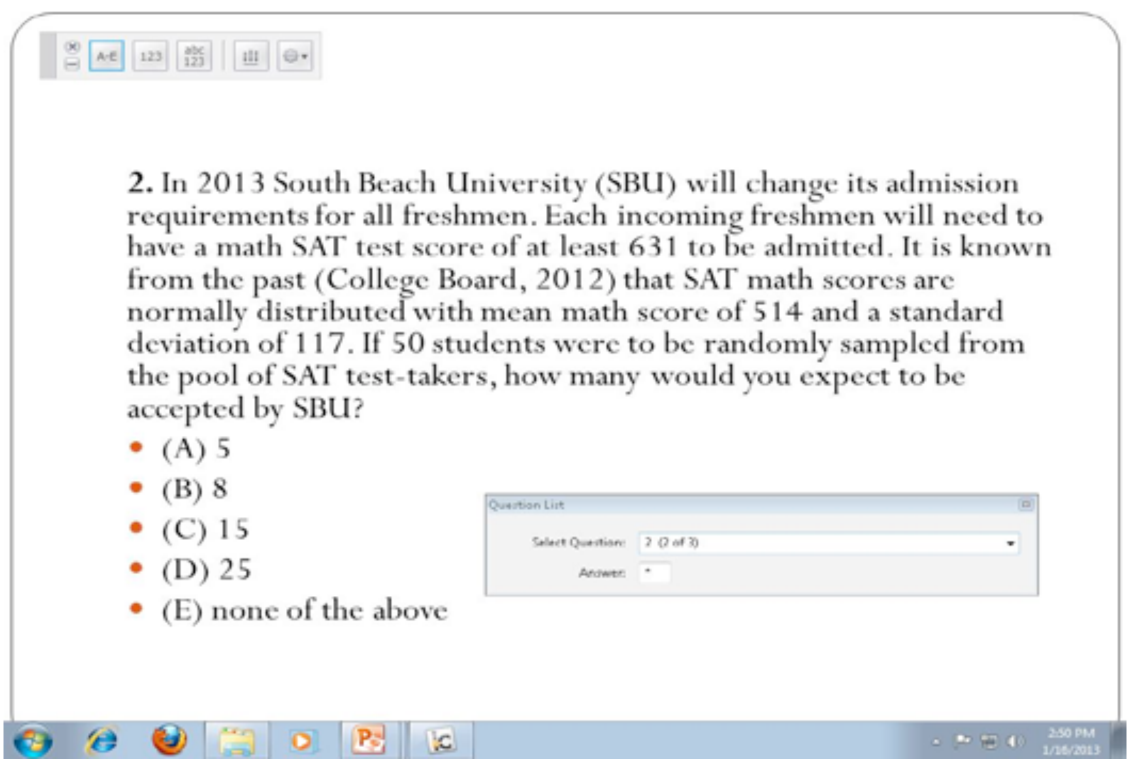
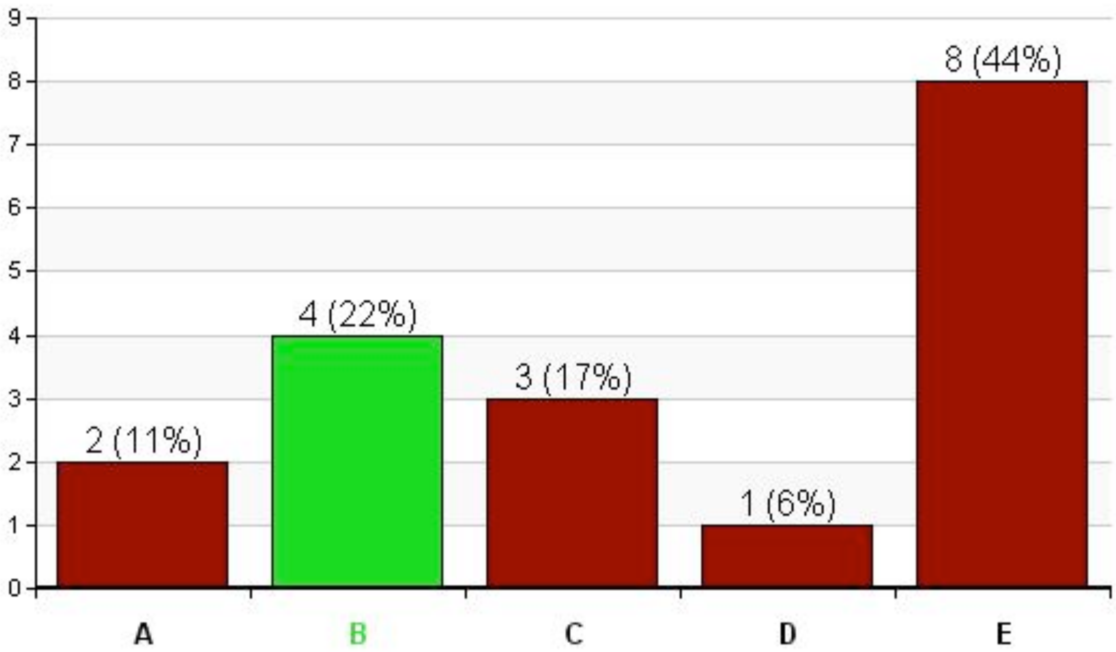


Figure 2. Clicker response



Murphy, McKnight, Richman, and Terry (2008) with values changed and the name of the university changed. In this example, only 22% of the students answered the question correctly (Figure 2), which provided the perfect opportunity to clarify some misunderstandings regarding the Empirical rule and the standard normal distribution. These results also illustrate the benefits of clickers, since the results are anonymous. This enables teachers to instantly gauge whether or not students understand a particular concept.

Results

Attendance versus Nonattendance

Attendance in both classes was taken using headcounts. Student who arrived late were counted as present. To double-check attendance in the clicker class, participation data records from iClickers were utilized. Figure 3 illustrates the attendance rates and trends based on headcounts conducted in both the clicker and nonclicker classes.

The 7th lecture was conducted on the last day of lectures prior to the Christmas holiday, and many students chose not to attend. Focus group participants provided reasons for not attending. Further, clickers were not used during the last two lecture meetings because students needed to work on their class projects. Each term, individual class projects are assigned, and they are worth 20% of each student's final grade. Based on Figure 3, attendance rates between the clicker and nonclicker classes appeared similar. Because participants were not randomly assigned to the clicker and nonclicker classes, a Mann-Whitney U test was run to determine if there were differences in attendance rates between the two groups. The median attendance rate for the clicker class (78%) and nonclicker class (82%) was not statistically significantly different, $U = 107.5$, $p = .43$, using an exact sampling distribution for U (Dineen & Blakesley, 1973).

To analyze how students perceived the clicker technology, 28 out of 33 students in the clicker class volunteered to complete a survey centered on a "clicker efficacy" scale developed by Haeusler and Lozanovski (2010). Each item on the "clicker efficacy" scale used a five-point Likert scale where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree (see Table 2). The instrument has an inter-item reliability of .89 and has been shown to be reliable based on the survey results given to science students (Haeusler & Lozanovski, 2010). On average, participants had positive perceptions about using clickers ($M = 3.77$, $SD = .70$), and the majority of students perceived clickers to be a

Figure 3. Attendance rates in clicker and nonclicker classes

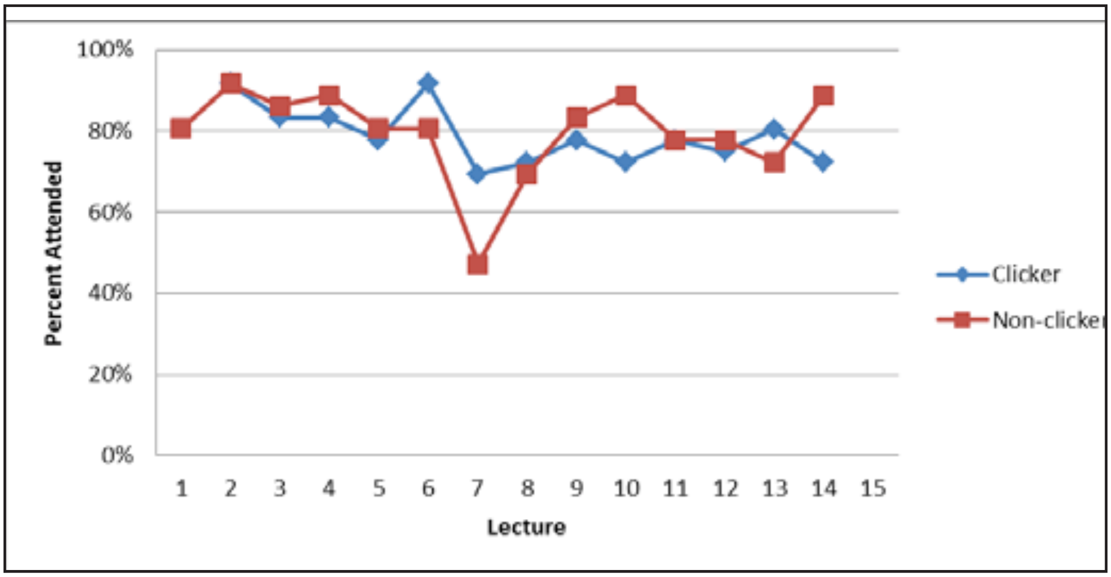


Table 2. Likert Questions on Student Perception of Clickers

Table 2. Likert Questions on Student Perception of Clickers

Question	% Agree	% Neutral	% Disagree	Mean ± SD
1. Using the clickers showed me where I stood in relation to the rest of the class.	54%	39%	7%	3.71 ± .94
2. Using the clickers helped me identify areas of strength and weakness in content knowledge.	78%	18%	4%	3.82 ± .91
3. Using the clickers made the classes interesting and engaging.	64%	22%	14%	3.61 ± 1.10
4. Using the clickers prompted discussions.	64%	25%	11%	3.71 ± 1.01
5. Using the clickers was a waste of time. ¥	14%	11%	75%	4.07 ± 1.09
6. Using the clickers assisted my understanding of the concepts that were discussed.	21%	43%	36%	3.75 ± .80
7. Using the clickers did not assist my learning. ¥	71%	22%	7%	3.86 ± .97

Note. ¥ denotes reverse coded item.

useful tool for introductory statistics. On average, learners also felt that clickers increased levels of engagement and made the class interesting. The question with the highest rated score was the reverse coded question: "Using the clickers was a waste of time." Thus, students indicated that they found the clicker technology to be a worthwhile addition in the course. Interestingly, 71% of the participants did not feel that clickers assisted their learning. This may be partly explained by the fact that the clicker questions did not align very well with examination questions; also, the participants' dissatisfaction with conducting the clicker questions at the beginning of the lecture may also have played a role.

Focus Group Results

Two focus group sessions also were conducted in the clicker class in order to analyze students' perception of clickers and their reasons for attending and not attending classes. The sessions consisted of 10 men and 10 women, and member checking was conducted after the group sessions to ensure the accuracy of the transcribed report. From the focus group sessions, five major themes emerged as factors that influence the likelihood of attendance: (a) medical emergencies and illnesses, (b) work, (c) college tuition costs/financial obligations, (d) time and day of the class, and (e) instructor/ facilitator.

Although reasons such as medical emergencies and illness are out of the hands of the instructor and have been documented in other research studies (e.g., van Schalkwyk et al., 2010), these same themes were again reported in the focus groups. For example, one participant stated, "The only time that I actually missed class was when I was sick or I really couldn't make it to class." Another participant reported similar reasons: "I was either sick or I just didn't wake up for class." The scheduled time of the class also seemed to influence attendance. Early morning classes, especially on Mondays, tend to be attended at a lower rate. One participant compared morning classes with the clicker class, revealing a tendency to miss morning classes but not classes in the middle of the day: "I'm usually awake by this time. For an 8:00 a.m. class, sometimes I just don't wake up." Some students try to attend even when they are sick. For example, one participant stated: "I would never miss a class, even if I was sick. Yes, I try not to. I don't want to get too far behind."

However, competing commitments and financial obligations can make it difficult for many students to attend. Often, students must choose between attending class and going to work. One participant stated the following:

> Most of the times like me it's two jobs and sometimes my second job wants me to come on certain days, usually in time frames where this class is going on. So do I need rent money, or do I need to come to class? Rent is naturally the first priority so that you can have a roof over your head, so that's why I sometimes don't come to class.

Another student explained how work and family commitment contributed to her nonattendance:

> I work over 40 hours a week, so it's kind of the reason why I don't put my priorities in order in the best way, and if I've missed class it's because I was out of state because that's where my family is.

Therefore, students typically feel like attendance is not an option when they need to work, experience an illness, or are involved in other medical emergencies. One participant stated: "Either I'm really sick or at work. I actually have a job to go to." Although all participants agreed that it is important to attend classes, there are cases in which their failure to attend is simply a result of the weather. Although one would expect bad weather to increase nonattendance, the focus groups indicated that good weather also invites poor attendance. For example, one participant stated:

> Just to share, when the weather is extremely good or bad you don't want to spend that period in the classroom; you want to be at home or outside. I had friends that flew up. I just hung out with them like a week or two, so I thought it was worth it to skip a class or [to] to spend time with them. They're only going be here a maximum of five days. So I chose to skip a class or two.

However, there are times when students simply do not attend because of instructional practices or a dislike of the instructor. One participant explained how he only attended a few times as a result of the instructor:

> Yes, I hated the professor. Like, [we] did not get along. So I said "You know what, here's my homework—I'm not going to show up until the final." We had like six papers, and I handed in all my assignments at the beginning of the semester. I had this person before, and we had a personal issue. I was like, "Give me my assignments and I will see you on the final."

Although the diversity of the campus is often embraced by students, faculties, and the administration, many foreign students leave early, before a break such the Christmas holiday and arrive after classes have started. This pattern was evident on the 7th lecture day shown in Figure 1. For example, one participant said, "Sometimes I might go back to my country, so I will ask to leave early and do a make-up test another day."

However, students are encouraged to attend by caring teachers who are able to develop a good relationship with their students and by teachers who are effective at presenting course material. For example, one participant was encouraged to attend classes solely because of the instructor. She stated:

> It goes back to why you attend the class regularly. Like, if the professor is making an effort to show up to teach you something, why not be there? So they do care. Often times, if they didn't care, they would tell you at the front door, "Get outta my class."

When courses are challenging for students (as introductory statistics courses often are), students also tend to attend at a greater rate. Therefore, the difficulty of a course seems to motivate students to attend. For example, one participant concluded that:

> The subject that I excel in I tend not to go as much versus a class that I don't know what's going on in. I try to show up more because I won't understand it if I don't attend.

Another participant tried to clarify and explain how and why he attended some classes:

> More like hard science classes you got to attend more, because if you miss like one part, you're not going to be able to move on. Classes like law classes something like that, you could miss one part of the subject and still be able to pick up next class. They tend to be interlinked but not dependent on each other. So, like, math classes and science classes tend to be more dependent upon one another.

Thus, attendance is promoted by teachers who are able to engage students and make the lesson and classroom environment exciting and fun for students. One participant recalled an experience in one of her courses:

> I had a professor two years ago who used to take the classroom experience and change it every time you went. He'll do one thing one day and another day something else. Because it was marketing, we'll play video games and then he'll go back and forth and joke and then we're having a meeting at another place at another time, and I think that was really entertaining because we didn't know what was going to happen. So, I think if classes were more like that they will draw more attention.

Another participant echoed a similar response:

> I will base it on the professor. The professor usually makes me want to come or not come every day. Usually if the professor is good and teaches you well, and you're actually learning and comprehending what they're saying, then yes, I'll be in class regularly.

Interestingly, the majority of participants preferred to be "forced" to attend if the instructor used participation points rather being mandated to attend by a mandatory attendance policy. One participant concluded that he would not attend classes if participation points were not part of the overall assessment in a course:

> Honestly, for me, I try to attend classes that are graded based on participation. For example, all these clickers motivated me to be present just because I know for a fact I'm losing something just for not showing up. But there are classes that don't require it.

However, the vast majority of participants enjoyed clickers, especially since they did not need to purchase them. For example, one participant stated:

> I like the clickers because I know like me some kids aren't like as vocal in class so maybe like their participation isn't as like high. I'm pretty loud all the time, but in Statistics, I'm not that smart, so I like that there's a clicker to help me with my participation grade. I also like that that this year we didn't have to buy them. Because I know freshman year I still have my clicker in this bag that I bought in one class so this is good for the upcoming kids. I know it stinks because you have to carry it [clicker set] to class everyday but is better than to spend $100 on a clicker that I used once.

Another participant explained how the classroom environment improved as a result of clickers:

> I feel like it makes the class a little bit more entertaining. Relating technology with the student. It makes them focus more or at

> least in my case. People are playing like they will shout out the answer, but if you actually look at it, you think about the question while you're sitting in your seat which answer you're going to choose and you do sit there and work it out and sometimes you do get the answer correct.

I heard similar responses in other lectured sessions when participants seemed disappointed when clicker questions were finished. All participants enjoyed the immediate feedback that clickers provided. One student agreed and added that clickers reduced her stress level when solving introductory statistics clicker problems:

> I think it takes away the anxiety of you taking a quiz and you handing it oh crap how did I do on that question. You get the immediate gratification that boom you clicked the answer it pops up and you know I either got the answer or I didn't. And you move on to the next one. You're no longer thinking about how did I do on that question. So a lot of times you don't know until the next class period and it's like two days later you go crap how did I do on that quiz.

However, focus group participants did not like it when students shouted out some of the answers before the clicker responses and answers were displayed. One participant suggested that I "make everyone not talk" during the clicker questions. Another participant explained that "sometimes when you're not sure, people shout out the answers, so then you pick that answer you get it wrong." Another participant explained the classroom environment:

> Because it's so interactive, people tend to take it more as a joke. When there's a quiz, it's all right you have to be quiet. With clickers, people tend to just play around more. So, they do tend to shout out the answer more, and it can screw you up. You get that self-doubt like so and so said that answer and they might be right.

Limitations

Ideally, participants would have been randomized when it came to creating the clicker and nonclicker classes. However, these participants could not be randomized, as they chose whether to be in the clicker or nonclicker class, though they were not aware of which section the intervention was going to be used in. Finally, even though the data was triangulated and every effort was made to ensure consistency in the treatment of participants in both classes, it is possible that learners from one group were unknowingly encouraged or motivated to attend more classes than the other group.

Discussion

The results from this study are consistent with other research findings. For instance, Morling, McAuliffe, Cohen, and Dilorenzo (2008) concluded that "attendance neither increase[s] nor decrease[s] over the semester" with clickers (p. 48). King and Robinson's (2009) study of 145 undergraduate engineering students also reported no statistically significant differences in attendance rates resulting from clicker use, "based on classroom observations" between a 2007–2008 cohort and a 2006–2007 cohort (p. 197). Further, Trenholm and Dunnet (2007) observed that "students not using clickers had even higher mean attendance levels than students using clickers" (p. 6). In their study, one section used clickers, one section did not use clickers, and one section was mixed. In the mixed section, some participants used clickers while others did not use clickers. Although the mixed class had a slightly higher attendance rate, the difference was negligible and nonsignificant.

All participants agreed that it was important to attend classes and admitted to being aware of the possible negative consequences of not attending. Nonetheless, students still had reasons to not attend. One participant stated: "I miss class sometimes because I'm sick. Sometimes, I'm just not feeling it for the day, or I just don't feel like listening to the teacher. It's bad, though." These results support the findings of Shannon (2006) and Doyle et al. (2008), which show that illnesses and medical emergencies decrease attendance. Other major reasons for not attending include spending time with friends or family, completing assignments for other classes, traveling, and particularly good or bad weather. These results were echoed in van Schalkwyk, et al.'s (2010) study. Poor teacher relationship and the quality of the lecture also contribute to nonattendance among participants. These results parallel the findings of Newman-Ford, Fitzgibbon, Lloyd, & Thomas (2008) and Doyle et al. (2008).

Missing classes due to financial obligations is a major theme that emerged during the focus group sessions. Participants expressed dissatisfaction about high tuition costs and resented being required to purchase clickers in the past. These financial obligations were seen as putting a strain on their ability to attend due to a need to work. Not attending as a result of part-time and full-time work was the most frequent reason for not attending. These findings support several previous studies (e.g., Doyle et al., 2008; van Schalkwyk et al., 2010).

Future Implications

This study suggests that when clickers are linked with a participation grade of five percentage points or less, attendance does not increase. Therefore, clickers do not magically increase attendance. A well-prepared, motivated, and caring lecturer who encourages participation and is able to establish a relationship with students is more likely to improve attendance and, in turn, can enhance the effect that clickers have on learners. Researchers interested in replicating this study should consider implementing clickers during other timeslots and on other days besides Mondays and Wednesdays to determine if similar nonsignificant results are obtained. Furthermore, because the majority of learners in this study had a positive perception of clickers, but they had reservations regarding the timing of clicker questions; in the future researchers should consider conducting clicker questions only during the middle or at the end of the lecture—not at the beginning.

Conclusion

Research studies on attendance in introductory statistics are limited. Besides work commitments, medical emergencies, and other uncontrollable factors, students cite boring classes, ineffective lectures, and a dislike of the lecturer as significant reasons to not attend (Fitzpatrick et al., 2011). However, the lecturer can attempt to influence students' behavior to attend by using the clicker technology to engage students while they remain anonymous. Even though the findings from the study revealed there were no statistically significant differences in attendance rates between learners in the clicker and nonclicker classes, clickers can change a classroom environment from a quiet, lecture-centered session into a game-like atmosphere that encourages communication and participation. Learners perceive the technology to be interactive and entertaining and they prefer earning participation points using the clicker technology rather than by listening to a teacher-centered lecture. Some participants even feel that the clicker technology reduces their stress level and provides a visual approach to learning. These attributes add a positive experience for learners and invite the implementation of other mobile devices (i.e., smartphones and tablets) into classrooms regardless of students' attendance records.

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References

Allen, S. G. (1981). An empirical model of work attendance. *Review of Economics & Statistics, 63*(1), 77.

Barlow, J., & Fleischer, S. (2011). Student absenteeism: Whose responsibility? *Innovation in Education and Teaching International, 48*(3), 227-237.

Bradley, C. (2009). Learning to live with statistics: From concept to practice. *Teaching Sociology, 37*(3), 322-324.

Clark, G., Gill, N., Walker, M., & Whittle, R. (2011). Attendance and performance: Correlations and motives in lecture-based modules. *Journal of Geography in Higher Education, 35*(2), 199-215.

Cleary-Holdforth, J. (2007). Student truancy in higher education. A phenomenon of student apathy or poor pedagogy? *Dublin Institute of Technology, Level 3*, 5. Retrieved from http://level3.dit.ie/html/issue5/cleary-holdforth/cleary_holdforth.pdf

Dineen, L. C., & Blakesley, B. C. (1973). Algorithm AS 62: Generator for the sampling distribution of the Mann-Whitney U statistic. *Applied Statistics, 22*, 269-273.

Dolnicar, S. (2005). Should we still lecture or just post examination questions on the web? The nature of the shift towards pragmatism in undergraduate lecture attendance. *Quality in Higher Education, 11*(2), 103-115.

Doyle, L., O'Brien, F., Timmins, F., Tobin, G., O'Rourke, F., & Doherty, L. (2008). An evaluation of an attendance monitoring system for undergraduate nursing students. *Nurse Education in Practice, 8*(2), 129-39.

Dunham, B. (2009). *Statistics clicks: Using clickers in introductory statistics courses*. Retrieved from http://www.cwsei.ubc.ca/SEI_research/files/Stat/ BDunham _ClickersInStat.pdf

Fitzpatrick, J., Cronin, K., & Byrne, E. (2011). Is attending lectures still relevant in engineering education? *European Journal of Engineering Education, 36*(3), 301-312.

Gok, T. (2011). An evaluation of student response systems from the viewpoint of instructors and students. *Turkish Online Journal of Educational Technology, 10*(4), 67-83.

Gupta, M. L. (2010). Interactive teaching and learning by using systems. *The International Journal of Learning, 17*(5).

Haeusler, C. E., & Lozanovski, C. (2010, December) *Student perception of clicker technology in science and mathematics education.* Paper presented at the 2010 Enhancing Learning Experiences in Higher Education Conference, Hong Kong. Retrieved from http://eprints.usq.edu.au/18154/1 / Haeusler_Lozanovski_2010_2 _PV.pdf

Hunter, S., & Tetley, J., (1999, July). Lectures. Why don't students attend? Why do students attend? Paper presented at the *HERDSA Annual International Conference*, Melbourne, Australia.

Kay, R. H., & LeSage, A. (2009). Examining the benefits and challenges of using audience response systems: A review of the literature. *Computers & Education, 53*, 819-827.

King, S. O., & Robinson, C. L. (2009).'Pretty lights' and maths! Increasing student engagement and enhancing learning through the use of electronic voting systems. *Computers & Education, 53*(1), 189-199.

Laxman, K. (2011). A study on the adoption of clickers in higher education. *Australasian Journal of Educational Technology, 27*(8), 1291-1303.

Massingham, P., & Herrington, T. (2006). Does attendance matter? An examination of student attitudes, participation, performance and attendance. *Journal of University Teaching and Learning, 3*(2), 82-103.

Milner-Bolotin, M., Antimirova, T., & Petrov, A. (2010). Clickers beyond the first-year science classroom. *Journal of College Science Teaching, 40*(2), 14-18.

Morling, B., McAuliffe, M., Cohen, L., & Dilorenzo, T. M. (2008). Efficacy of personal response systems ("clickers") in large introductory psychology classes. *Teaching of Psychology, 35*, 45-50.

Murphy, T. J., McKnight, C., Richman, T., & Terry, R. (2008). *Clicker questions*. Retrieved from The University of Oklahoma, http://www.ou.edu/statsclickers /clickerQuestions.htm

Newman-Ford, L., Fitzgibbon, K., Lloyd, S., & Thomas, S. (2008). A large-scale investigation into the relationship between attendance and attainment: A study using an innovative, electronic attendance monitoring system. *Studies in Higher Education, 33*(6), 699-717.

Prather, E. E., & Brissenden, G. (2009). Clickers as data gathering tools and students' attitudes, motivations, and beliefs on their use in this application. *Astronomy Education Review, 8*(1).

Revell, A., & Wainwright, E. (2009). What makes lectures 'unmissable'? Insights into teaching excellence and active learning. *Journal of Geography in Higher Education, 33*(2), 209-223.

Rodgers, J. R. (2002). Encouraging tutorial attendance at university did not improve performance. *Australian Economic Papers, 41*(3), 255-266.

Romer, D. (1993). Do students go to class? Should they? *Journal of Economic Perspectives, 7*(3), 167-174.

Shannon, S. J. (2006, December). Why don't students attend lectures and what can be done about it through using iPod nanos? Paper presented at the *23rd ASCILITE Conference: Who's learning? Whose technology?* The University of Sydney, Australia. Retrieved from http://www.ascilite.org.au/conferences/ sydney06 //proceeding/pdf_papers/p28.pdf

Steers, R. M., & Rhodes, S. R. (1978). Major influences on employee attendance: A process model. *Journal of Applied Psychology, 63*(4), 391-407.

Trenholm, B., & Dunnett, J. (2007). When it all "clicks"—the effectiveness of using game show technology in the classroom. *Financial Education Association, Bermuda*. Retrieved from http://abeweb.org/proceedings/proceedings07/Bdunnett.pdf

van Schalkwyk, S., Menkveld, H., & Ruiters, J. (2010). What's the story with class attendance? First-year students: Statistics and perspectives. *South African Journal of Higher Education, 24*(4), 630-645.

Wood, D. M., Burke Da Silva, K. L., & Menz, R. I. (2007, July). *Are the benefits of clickers due to the enforcement of good pedagogy?* Paper presented at the 30th HERDSA Annual Conference, Adelaide, Australia. Retrieved from http://www.herdsa.org.au/wp-content/uploads conference/2007/papers/p179.pdf

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