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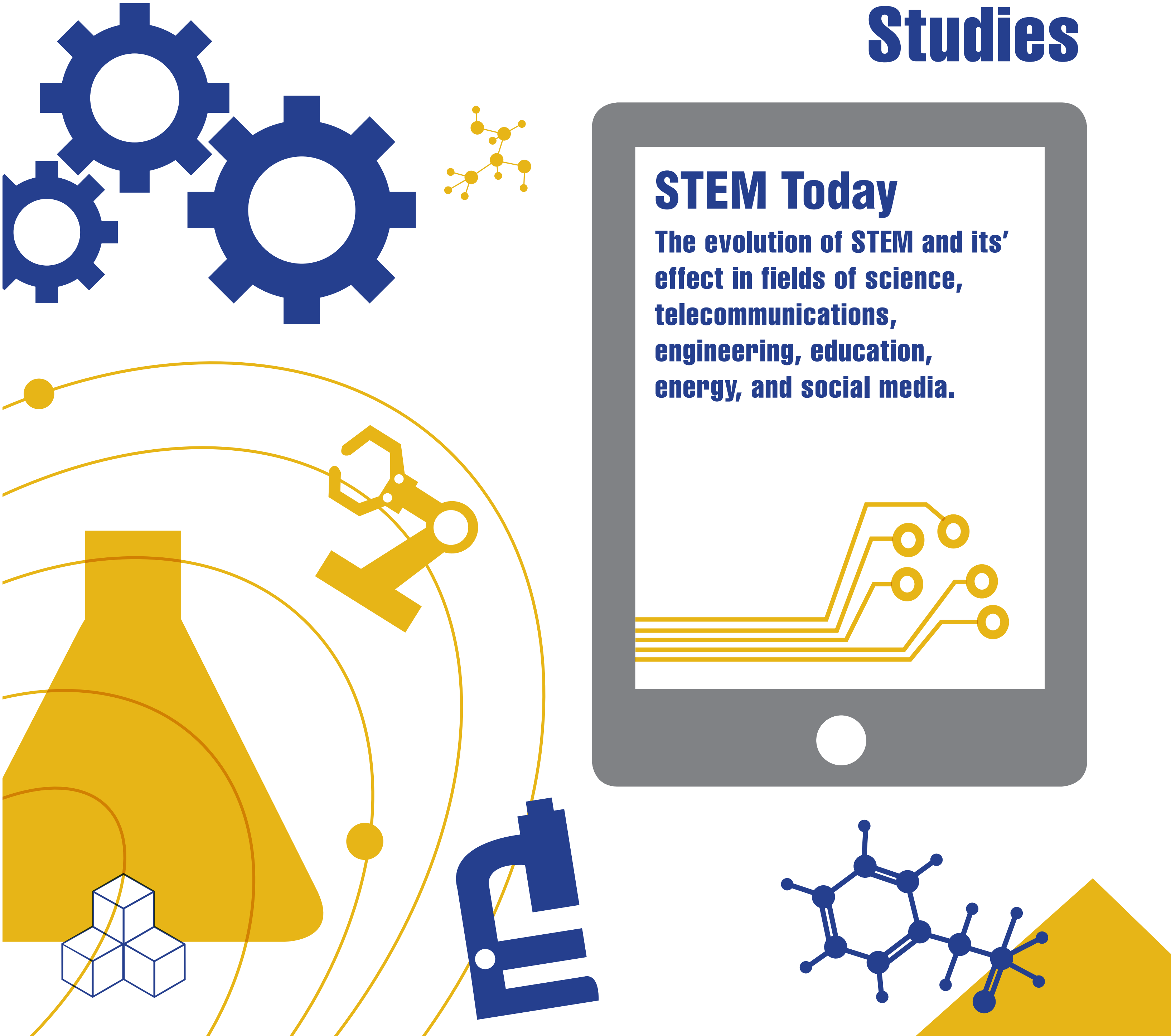

A refereed publication of Epsilon Pi Tau The International Honor Society for Professions in Technology.

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Jerry Streichler, Founding Editor and Publisher from 1977-2006, who passed away on July 2, 2015

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Volume XLI, Number 1, Spring 2015

Proposed Progression of Lean Six Sigma

By James Taylor, John Sinn, Jeffrey M. Ulmer, and M. Affan Badar

ABSTRACT

Lean Six Sigma is a hybrid continuous improvement methodology that has various definitions, from those that are Lean dominant to those that are Six Sigma dominant. Text mining and cluster analysis based research has helped to illuminate the degree to which Lean Six Sigma models, as described in articles published in the International Journal of Lean Six Sigma, are Lean dominant versus Six Sigma dominant. The iterative cluster analysis was used to identify clusters of articles that were interpretable. The research found that some Lean dominant Lean Six Sigma articles ascertain Lean as the dominant philosophy and Six Sigma as a subordinate tool used in achieving the Lean objectives. The findings of this research as well extrapolation of the literature informed a recommended Lean Six Sigma model as described in this article. The recommended model is Lean dominant and consists of two subordinate methods – Six Sigma and statistical process control. The three synergistic approaches not only each serve in their own way to manifest process improvements, they also all contribute to organizational learning, which is considered a chief contributor to competitive advantage.

INTRODUCTION

Lean and Six Sigma respectively are widely popular process improvement approaches used around the world (Snee, 2010). In recent years Lean and Six Sigma are being integrated into what is commonly called Lean Six Sigma (Snee, 2010). The integration of Six Sigma (Corbett, 2011), which focuses on processes, with Lean, which focuses on the connection between process steps (Antony, 2011), is supported by both practitioners and scholars. The purpose of this research was to explore the theory and definition of this integration. Currently, a standard framework for Lean Six Sigma is lacking (Pepper & Spedding, 2006).

Lean, as Derived from the Toyota Production System

The Toyota Production System was developed at Toyota Motor Manufacturing as far back as the middle of the last century, with Taiichi Ohno as the chief architect (Mayeleff, Arnheiter, & Venkateswaran, 2012). The mantel within Toyota was to eradicate all waste (Pepper & Spedding, 2010), which leads to improved quality, which furthermore leads to reduced costs and increased productivity, in accordance with the Deming Chain Reaction (Deming, 1986). The Toyota Production System (TPS) was the forerunner for what is known today as Lean (Pepper & Spedding, 2010).

The Toyota Production System (TPS), using the analogy of a house in order to facilitate ease of understanding, consists of two key pillars (Smalley, n.d.). The first pillar is known by its Japanese name 'jidoka' which refers to the principle of designing processes so as to maximizing inherent quality (Smalley, n.d.).

The second principle of the Toyota Production System is the just-in-time (JIT) pillar (Smalley, n.d.). The JIT pillar has two underlying objectives, the first being more intuitive than the second. The first objective is to ensure the manufacturing and distribution of "the right parts, in the right amount, at the right time" and doing this in the most efficient manner possible using the minimum resources (Smalley, n.d.). A second, less obvious objective of the JIT system is that it creates a system that exposes problems, which might otherwise be generally shielded by extra inventory, sometimes referred to as safety stock; the security of ongoing production is protected by backup inventories (Smalley, n.d.). The philosophy of this second objective is that the urgency that a threatened shut down might incur creates an even greater urgency for addressing and fixing the underlying problem, both thoroughly and permanently (Smalley, n.d.). The concept of making problems visible and addressing them as a top priority is a high level priority throughout the Toyota Production System (Chiarini, 2011; Smalley, n.d.).

The heart of TPS is the employees, by whom Lean objectives are realized, under the coaching of management (Assarlind, Gremyr, & Backman, 2012; Smalley, n.d.). While complex problems may be typically addressed with the Six Sigma methodology, Lean initiatives more frequently address “every day waste,” which draws upon the participation of the broader base of employees (Corbett, 2011).

Six Sigma

Utilizing a statistical, data-based scheme (Chiarini, 2011), the Six Sigma approach optimizes processes by determining the relationship between critical process inputs and the essential process outputs, and resetting the inputs accordingly (Oguz, Kim, Hutchinson, & Han, 2012). The theoretical equation that represents the essence of the Six Sigma problem solving method is $Y = f(X)$ (Oguz, et al., 2012). The Y represents the process output and the X represents the critical inputs that drive the performance of the output (Oguz, et al., 2012). Understanding and controlling the pertinent inputs facilitate solutions, which optimize process outputs (Oguz et al., 2012). Six Sigma originated as a quality focus for reducing process variation (Assarlind et al., 2012; Chiarini, 2011), leading to near zero breaches of specification limits, and thereby, near zero defects (Corbett, 2011; Mayeleff et al., 2012; Oguz, Kim, Hutchinson, & Han). The Six Sigma approach can be used to reduce variation about the target, realign the process center with the target, or both (Antony, 2011; Dumitrescu & Dumitrache, 2011).

Lean Six Sigma

Lean Six Sigma (LSS), while being widely utilized manifests in differing expressions that do not lend itself to coalescence about a standard definition (Assarlind et al., 2012). It is generally inferred that Lean Six Sigma consists of an integration of the two independent methodologies: Lean and Six Sigma (Assarlind et al., 2012; Corbett, 2011). The expectation is that the merging of the two results in a magnified advantage. There are a number of different ways in which the integration is manifest however Salah, Rahim, and Carreto (2010) stated insightfully that, “the integration needs to achieve a full fusion of the Lean philosophy of waste elimination with the Six Sigma mentality of perfection.” LSS blends the focus on process flow by Lean with the Six Sigma spotlight on improved capability by virtue of diminished variation (Chiarini, 2011; Oguz et al., 2012). Integration is not achieved when Lean and Six Sigma are alternatively deployed, as per menu options (Salah et al., 2010).

Pepper and Spedding (2010) developed an LSS integration model that reflects that Lean is the dominant methodology and that Six Sigma is used in a subordinate role. This model constitutes a comprehensive management approach addressing all manner of business process improvement (Pepper & Spedding, 2010). Figure 1 depicts this integration model. The Lean ideology represents the key foundation of the improvement model, not unlike what has been demonstrated at exemplary firms such as Toyota (Pepper & Spedding, 2010). In the pursuit of the Lean ideal state, obstacles, referred to as “hot spots,” are encountered (Pepper & Spedding, 2010). Tactically, Six Sigma is deployed at these hot spots “driv[ing] the system towards the desired future state” (Pepper & Spedding, 2010). These hot spot obstacles may be more effectively addressed with Six Sigma due to the analytical superiority of the Six Sigma system, enabling the process to gain progression towards a goal

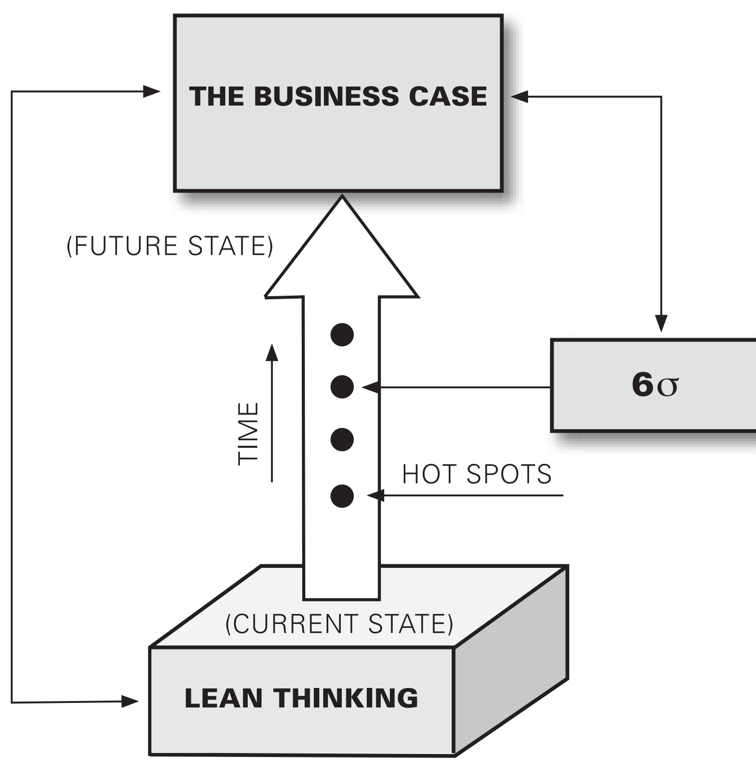

Figure 1. Conceptual Model for Lean Six Sigma
(Pepper & Spedding, 2010)

of true Lean existence (Pepper & Spedding, 2010). This model is not completely novel in that many firms deploy an integrated LSS approach by "apply[ing] basic Lean tools and techniques at the starting phase of their program such as a current state [value stream] map, basic housekeeping using 5S practice, standardized work" (Antony, 2011). The simpler Lean approaches used at the vanguard of the roll out remove many of the ground level wastes, leaving and often further revealing the more complex, and often persistent, "hot spots" that can be effectively tackled with the Six Sigma approach (Antony, 2011; Pepper & Spedding, 2010).

Need for a New Model

There are myriad ways to combine Lean and Six Sigma (Pepper & Spedding, 2010). One common Lean Six Sigma model consists of Lean as an overriding production philosophy (Pepper & Spedding 2010). As obstacles are encountered along the Lean journey, Six Sigma is deployed as a tactic to tackle complex obstacles (Pepper & Spedding, 2010). Lean thinking establishes a target condition whereas Six Sigma is used to address deviations from the target (Cheng, 2010). This Lean dominant approach benefits from the problem solving methodology that Six Sigma brings to bear (Pepper & Spedding, 2010). With such a Lean Six Sigma hybrid, Six Sigma is a subordinate component that is absorbed into Lean as the dominant model (Salah *et al,* 2010). Pepper and Spedding (2010) propose such a Lean dominant model. Lean thinking establishes the business case and the direction for the organization. As the objectives are pursued, obstacles identified as "hot spots" are encountered. Six Sigma provides a focused problem solving approach for dealing with these "hot spots" (Pepper & Spedding, 2010), which propels the organization forward.

Alternative is the model wherein Lean is subordinate to Six Sigma. This Lean Six Sigma model originates from and is driven by the Six Sigma community (Hill & Kearney, 2003; Jing, 2009; Smith, 2003). For many practitioners, Lean Six Sigma is essentially Six Sigma with Lean tools incorporated (Bendell 2006; Chiarini, 2011; de Koning, Verver, van den Heuvel, Bisgaard, & Does, 2006; Gershon & Rajashekharaiah, 2011). This lack of true integration of the systems is further reflected in that Six Sigma oriented authors use the term Lean Six Sigma interchangeably with Six Sigma (Snee, 2010). Snee even goes on to discuss the integration of Lean manufacturing with Lean Six Sigma, implying that Lean Six Sigma is simply Six Sigma reconstituted.

Snee (2010) proposed that business and process performance goals establish the business case and that deviations from goals lead directly to Six Sigma projects, or indirectly by way of value stream mapping analysis. Depending upon targets that are derived from value stream mapping, a Six Sigma project, a kaizen event, or a quick hits action is selected. These three options are the means by which to address the performance gaps, and they may also inform and lead to each other (Snee 2010). The objective overall is to achieve business excellence by continuously making improvements (Bhuiyan & Baghel, 2005).

Thus far academia has paid scant attention to Lean Six Sigma (Hoerl & Snee, 2010; Ngo, 2010, p. 18). Lean Six Sigma methods need to be supported by sound theory that is scientifically underpinned (Pepper & Spedding, 2010) and theory needs to be continually challenged and enhanced (Snee 2010). This work was an attempt to develop an optimal Lean Six Sigma model system based on the assessment of characteristics, differences and dominance.

A Derived Model for LSS

Taylor (2014) researched Lean Six Sigma models as the topic of dissertation research. A review of literature found that the spectrum of Lean Six Sigma approaches extends from those that are Lean dominant to those that are Six Sigma dominant. This research illuminated the Lean Six Sigma methodology by methodically assessing the literature via text mining and cluster analysis. Text mining was used to establish the degree to which Lean Six Sigma models, as described in articles published in the International Journal of Lean Six Sigma, are Lean dominant versus Six Sigma dominant. The iterative cluster analysis was used to identify clusters of articles that were interpretable. A cluster of Lean dominant Lean Six Sigma articles was identified and statistically validated as being distinct from other models. It was determined that characteristics of a Lean dominant Lean Six Sigma include the text mining key words "waste," "value," and

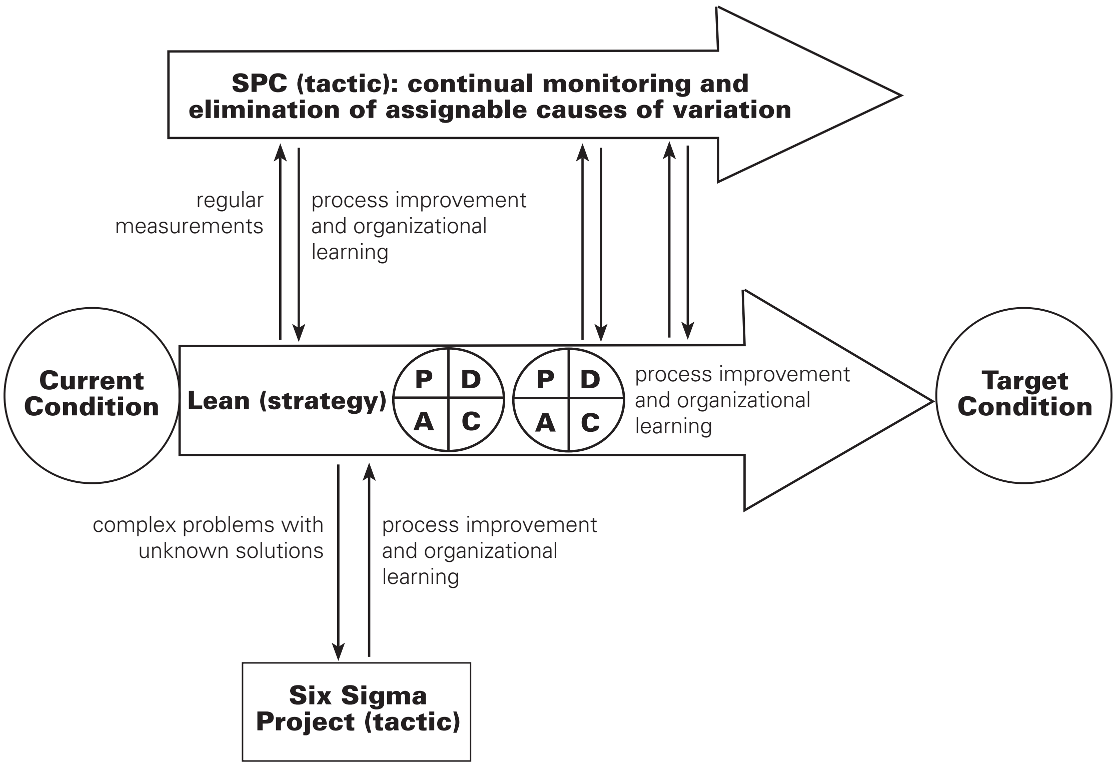

Figure 2. Derived and Recommended Lean-Six Sigma-spc (Lssspc) Model
(Taylor, 2014)

"kaizen." The research also found that these Lean dominant Lean Six Sigma articles ascertain Lean as the dominant philosophy and Six Sigma as a subordinate tool used in achieving the Lean objectives. The findings of the research as well extrapolation of the literature informed a recommended Lean Six Sigma model.

Differing LSS models were evaluated for meeting the intent of the root methodologies, Lean and Six Sigma, as well as for continuous improvement theory in general (Taylor, 2014). A LSS model which best satisfies these intents was derived and recommended.

The derived and recommended model differs from any other model identified thus far in that it introduces statistical process control (SPC) as another tactic, wherein the model is hereby named Lean-Six Sigma-spc (Lssspc) (Taylor, 2014). These three methods, one dominant and two subordinate, have been synthesized into a derived and recommended model, as supported by the literature. This model, which is informed by the data mining research as well as an extrapolation of the literature, is shown in Figure 2.

This Lssspc model (Taylor, 2014) is a Lean dominant model that holds up Lean as the strategic element (Hines, Holwe & Rich, 2004; Pepper & Spedding, 2010). The Lean model consists of establishing a target condition, comparing that target to the current condition, and then following the established Lean principles and practices – in particular the plan-do-check-act (PDCA) method of continual kaizen experimentation by the workforce at large – in pursuit of the target condition (Rother, 2010). Not only will the process be improved, but organizational learning will also occur, which may largely contribute to a sustaining competitive advantage (deMast, 2006). In support of this Lean dominant strategy, there are two supporting tactics that operate in parallel (Taylor, 2014). Six Sigma can be used as a tactical project tool to address complex problems with unknown solutions (Snee, 2010), as depicted in the LSS model proposed by Pepper and Spedding (2010). For each Six Sigma project deployed as such, processes will be improved and organizational learning will occur. Secondly, statistical process control (SPC) will be deployed at regular intervals for monitoring key metrics, and elimination of assignable cause variation detected therein (Wheeler, 2007). This practice also leads to process improvement and organizational learning.

Discussion and Conclusion

The data mining research corroborates the presumption that Lean Six Sigma is not standardized (Taylor, 2014). A model which depicts LSS as being indistinguishable from classical Six Sigma is anecdotally very prevalent in the consulting and publishing realms. A training manual provided by Open Source Six Sigma which is entitled *Lean Six Sigma Black Belt* (2007) is essentially the same as the Six Sigma manuals that Taylor has used for many years.

An important distinction concerning improvement methodologies pertains to why they benefit the organization that adopts and implements them. de Mast (2006) writes that the sustaining benefit of Six Sigma is not in the results that are realized project-by-project. These results, he argued, can be replicated by competitors that enable an organization to not suffer competitive disadvantage; they are not a source of sustainable competitive advantage. His research argues that sustainable competitive advantage is generated by the competencies that are developed as a result of practicing Six Sigma. These competencies, developed as in organizational learning are not easily replicated. Approaches to immediate results and organizational learning are afforded in the proposed LSS model in three ways. The PDCA method as used by Toyota (and others) is the cornerstone of the Lean strategic approach (Rother, 2010). The lower level problem solving methods typically used in Lean, such as PDCA, are often insufficient for resolving complex matters (Pepper & Spedding, 2010). Second, the Six Sigma approach of addressing complex problems in a tactical way (Pepper & Spedding, 2010) is merged into this model. Third, statistical process control is continually applied to process metrics as a tactical means of identifying and correcting special causes of variation, and as is often the case, defects. Classical Six Sigma models consider SPC as a subset of Six Sigma, predominantly in the control phase as a monitoring tool (Stauffer, 2008). There are some that argue for a more integrated approach of SPC in the measure and/or analyze phases, given that some problems are of an assignable cause nature and can be resolved more efficiently with SPC than with the Six Sigma project method (Stauffer, 2008; Wheeler, 2007). It is this theory and logic upon which SPC was integrated into the Lssspc model.

An important criteria for consideration for all manner of LSS models is the degree to which its emphasis is on tactical versus strategic. While Six Sigma has been proposed as a strategic approach, Lean has clearly been delineated as a long-term strategy (Hines et al., 2004) that is exemplified by such world-class organizations as Toyota. For this purpose, in agreement with Pepper and Spedding (2010), this recommended LSS model presents Lean as the superordinate strategic framework, supported tactically by Six Sigma and statistical process control (Taylor, 2014). For future work, it is recommended to apply the LSS model developed in the present article on a case study.

Lean, Six Sigma, and Lean Six Sigma are all variants of continuous improvement systems which have evolved from focused methodologies. Organizations will continue to evolve their improvement methodologies and as such, there is only a limited shelf life for any given model. As in the marketplace of goods as well as with the marketplace of ideas, those that bring value will sustain and those that are inferior will be neglected.

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Assessing the Cost Effectiveness of LEED Certified Homes in Kentucky

By Stephen J. Glossner, Sanjeev Adhikari, and Hans Chapman

ABSTRACT

The purpose of this study was to analyze the cost effectiveness of building new-construction single-family homes through the Leadership in Energy and Environmental Design (LEED) program in six counties of Kentucky. The estimated added LEED construction cost was calculated as well as its respective payback period based on the expected utility savings of LEED certification. A mortgage cost comparison was also performed comparing traditional code built to non-LEED single-family homes. Using descriptive statistical analysis on the simple payback period, mortgage costs were compared internally and by county. This study found that The LEED Certified and Silver level had payback periods less than 30 years, and the total 30 year net difference between non-LEED and LEED certified ranged from $-1,193.20 to $1,667.64.

Keywords: Leadership in energy and environmental design (LEED), sustainability, residential construction, LEED cost

INTRODUCTION

In the United States, increasing significance is being placed on the practice of sustainability mostly in part to energy price increases and environmental concerns. In 2010, the United States consumed 95 quadrillion BTUs of energy accounting for 19% of the world's energy consumption for that year. Of that 19%, 81% was produced by fossil fuels and only 9% was produced by renewable energy sources (U.S. Energy Information Administration 2013). This has pushed for the practice of sustainable design to become the standard for new construction projects, especially in the residential sector. The LEED certification program led through the U.S. Green Building Council (USGBC). This program evaluates construction projects on the various sustainable design features and materials and offers four levels of certification.

It is clear that sustainability is going to be a significant factor in all construction fields as energy prices continue to increase and resources become increasingly scarce. Since 2000, The LEED program has been at the forefront of sustainability in the commercial industry (Schmidt 2008). In 2008, an estimated 5% of public buildings in the United States were LEED certified (Schmidt, 2008). The number of LEED-certified residential units have significantly increased annually since the LEED for Homes program's conception in 2007 (Kriss, 2014); there were 392 certified residential, while in the last recorded year – 2013 – 17,000 residential units were certified. This trend is likely to continue for 2014. This level of annual increase is not apparent when considering the increase of LEED-certified homes at the state level. One such state is Kentucky. Kentucky only has 55 homes that were certified between 2008 and 2013, and 46 of those 55 homes were part of a military community established in Fort Knox (USGBC, 2005).

There could be several factors contributing to this low number. The information that is available to the public is lacking in Kentucky. There is an unknown cost associated with constructing LEED-certified homes. McGraw-Hill Construction identified the cost perception as a top obstacle to green building for both homeowners and builders. Changing this cost perception is the main priority for the USGBC and green building community in its entirety (Schmidt, 2008). Making information regarding the added cost of pursuing LEED certification and the associated utility cost savings is essential to the advancement of the LEED for Homes program in Kentucky.

One of the contributing factors to the low number of LEED-certified residential projects in Kentucky could be the lack of organized information pertaining to LEED certification of residential projects, specifically the cost and economic information of LEED-certified versus traditional code built single-family homes in Kentucky. The LEED for homes rating system has only been officially recognized since 2008, resulting in limited available data. This lack of available data makes it difficult for individuals to be informed about LEED homes and how they compare to traditional code-built homes. One of the most significant factors for homebuilders and homebuyers alike when considering building a new home is cost, especially when considering a new idea such as LEED. Though there are many benefits to a LEED-certified home, both financially and environmentally, these are overshadowed by cost uncertainties.

The primary and secondary purpose of this study was to assess the cost effectiveness and provide more information to homebuilders and potential buyers regarding LEED-certified single-family homes in (Fayette, Jefferson, Campbell, Kenton, Boone, and Spencer County) Kentucky. The fundamental purpose of this study was that the findings would attract more LEED certified residential projects to Kentucky by showing that the construction cost difference between traditional code-built and LEED-certified homes is not significant.

Brief History of LEED

The United States Green Building Council was established in 1993. In April of that year the first council meeting was held, and it consisted of 60 construction firms and a few nonprofit organizations (USGBC, 2014). The Leadership in Energy and Environmental Design program was launched in March 2000. At the time the USGBC was founded, there was much conjecture on what a "green building" was and how to develop a uniform code to standardize the green buildings (Kriss, 2014). The LEED program has evolved from a list of best practices to a highly organized method of rating green buildings. Five LEED programs exist, and each includes specific project types and credits. In 2000, 51 projects were part of the very first LEED for new construction rating system (USGBC, 2012).

The LEED program is a set of building standards and practices that operate on a credit-based rating system organized by categories. There are five of these main credit categories, and each has a set number of possible LEED credits. Some categories have prerequisites that must be met and no credit is awarded for. The LEED for Homes rating system began as a pilot program in 2005, and by 2006 the first LEED for homes project was certified in Oklahoma City, OK (USGBC, 2015). The LEED for Homes program became official in 2008 (USGBC, 2015). There are eight credit categories for the LEED Homes rating system, and each category is divided into subcategories. The LEED for Homes certification process consists of four steps: registration, verification, review, and certification (USGBC, 2015).

Mapp, Nobe, and Dunbar (2011) compared the cost of eight non-LEED banks and two LEED-certified banks with similar building types and sizes located in western Colorado. The purpose was to assess the cost directly associated with seeking LEED certification using total building cost, square footage cost, soft costs, and hard costs. Findings from this study show that when the total building cost per square foot of the LEED certified banks were compared with the eight non-LEED certified banks they were within the square footage costs for all ten banks. This study also estimated the direct cost associated with LEED certification and found that the direct costs LEED certification were below 2% of the total project cost and between 1.5% and just over 2% of the total building cost. It was concluded that across very similar projects it was possible to achieve LEED certification for minimal additional costs, and the costs associated with the LEED projects were always within the overall range of the non-LEED projects (Mapp et al., 2011).

Reposa (2009) compared the applicability, requirements, verification, fees, and construction cost for LEED for Homes to two other NAHB residential green rating programs. He found that the fees associated with LEED for Homes range from \$50 to \$100 for enrollment, \$250 to \$400 for certification, \$300 to \$1,000 for the provider, \$100 to \$150 for initial dry wall inspection by Green Rater, and \$350 to \$700 for second inspection and document review by the Green Rater. This resulted in a total added cost of fees for LEED certification to be \$1,050 to \$2,350. The study also reported that the cost of fees could increase, depending on the level of familiarity the subcontractors have with the LEED for Homes rating system. Inexperienced subcontractors may require on the job training, which costs approximately \$150 per. It is important to note that subcontractors who are inexperienced with the LEED program and its procedures are a significant factor in the added cost in both fees and construction. The level of experience causes significant variability in the added cost of LEED for Homes certification. Mr. Mullen, the Director of Residential Business Development for the USGBC confirmed that the experience of the general contractor and subcontractor can have a significant effect on the added cost for LEED certification. Reposa (2009) reported the additional construction-compliance cost for the four levels of LEED certification. This study found that the added construction costs for LEED- certified single-family homes represented an increase of 4 to 6%; the added cost of a LEED Platinum level single-family home represented an added cost of 20 to 22%. The LEED for Homes program had the highest added cost of all three programs used in the study. The LEED for Homes program cost was nearly double the other two programs.

It is important to note that the above figures from Reposa (2009) were estimated using only two model homes from varying geographic locations. These results may not reflect the most accurate estimated added construction cost for LEED certification in Kentucky based off of an interview with a homebuilder that built a LEED Gold certified single-family home in the Northern Kentucky area. The interviewed homebuilder built a LEED Gold certified single-family home and stated an estimated additional construction cost of $10,000.

Based on the limited information pertaining to LEED certified single-family homes in Kentucky; this study was performed in order to relate the cost effectiveness of building LEED certified single-family homes to Kentucky. This was achieved by using utility cost, home cost, and home size sample populations taken from select counties in Kentucky to determine if the initial added cost was financially justified by the expected monthly utility cost savings.

Objectives

There are two primary objectives of this study. One centers on the construction cost of LEED certification, whereas the other deals primarily with the financial justification of the LEED construction cost. The two objectives follow:

1. Determine the estimated added construction cost of a LEED-certified single-family home in the selected counties of Kentucky (Fayette, Jefferson, Spencer, Boone, Kenton, and Campbell County).
2. Analyze the cost effectiveness of a LEED-certified single-family home in the selected counties of Kentucky (Fayette, Jefferson, Spencer, Boone, Kenton, and Campbell County).

Added Construction Cost

It is apparent that there is an added construction cost associated with building LEED certified homes. For this study descriptive statistical analysis was used, in conjunction with data and findings from the USGBC and the National Association of Home Builders (NAHB), on a sample size of least 20 homes per county to estimate the added construction cost of each LEED level in each county and analyze the results. Multiple listing services were used to collect the sample population for each county. In order for a home to qualify to be used in the sample population the following criteria had to be met: (a) single-family (b) new construction (c) 3-4 bedrooms (d) 2-3 bathrooms (e) no added sustainable features, and (f) no added-value items. The NAHB periodically conducts a study regarding cost of a new- construction single-family home based on surveys taken from homebuilders across the United States. This study breaks down the total cost into seven categories, according to cost and percentage of the total sale value of the home. The 2013 NAHB survey shows the construction cost of a home was 61.7% of the total value of the home (Taylor, 2014). For the purposes of this study the construction cost of the sample homes were obtained using the 61.7% of the list price.

The added construction cost associated with each LEED level was calculated using a percentage of the estimated construction cost mentioned above. The added LEED percentages are as follows: (a) LEED Certified 4%, (b) LEED Silver 7%, (c) LEED Gold 10%, (d) LEED Platinum 13%. These percentages were figured through communications with LEED professionals and homebuilding organizations that have previously built LEED certified homes. The average added construction cost of a LEED Certified level home stated by the Director of Residential Business Development for the USGBC was around 3% (Mullen, personal communication, January 25, 2014). For this study a 4% added construction cost for a LEED Certified level home was used. The added construction cost for a LEED Gold single family home reported by a homebuilding organization in Covington, Ky. was 9% (Petronio, personal communication, January 26, 2014). For this study a 10% added construction cost for a LEED Gold level home was used. The Silver and Platinum level percentages (7% and 13%) were based on intervals using the Certified and Gold level percentages.

The added percentages for all four levels of LEED certification were applied to each of the construction costs. Equation 1 was used to extract the added construction cost from the home list price. Each sample home's construction cost yielded four figures representing the added cost for each level of LEED certification.

$$(\text{List Price}\times 0.617) \times (0.04, 0.07, 0.10, \text{ and } 0.13) = \text{Added LEED Construction Cost} \ldots\ldots \quad (1)$$

Cost Effectiveness of LEED Certified Homes

The added LEED construction cost data was used for the payback period analysis and 30- year mortgage analysis with the addition of monthly utility costs for traditional and LEED- certified single-family homes. Descriptive statistical analysis was performed on the payback period results for each LEED level in each county to compare the payback periods internally and against the other counties.

The method was to use the data provided by the USGBC on the utility efficiency of LEED certified homes. According the USGBC, LEED for homes projects, on average, are 20% to 30% more efficient than a typical residential project built to code (USGBC, 2005). The LEED for Homes program mandates that a home must be Energy Star certified before it can be LEED certified. The Energy Star program states that Energy Star certified homes are at least 15% more efficient compared to traditional code built homes. Based on the Energy Star prerequisite a LEED home is, at minimum, 15% more utility efficient than a traditional code built home. The percent reduction figures chosen for this study are as follows and apply to both the payback period analysis and 30-year mortgage analysis: (a) LEED Certified 15%, (b) LEED Silver 20%, (c) LEED Gold 25%, and (d) LEED Platinum 30%. The sample populations for each county are shown in Table 1.

Payback and Mortgage Analysis

For Fayette, Jefferson, Spencer, Boone, Kenton, and Campbell County the payback period for each LEED level was calculated by dividing the added the construction cost by the respective utility savings per month. The utility cost used in the payback period analysis was based on a cost per square foot. The average monthly utility cost in Kentucky in 2011 was $148 (Wheeland 2012). The $148 monthly utility cost was based on expenditure tracking on utilities from January through October, 2011. Accounting for 2% inflation, the monthly utility cost in 2013 translates to $154. The $154 was divided by the median square footage of all six counties (2116 sq. ft.) yielding $0.073 per square foot. The estimated utility cost for each sample home was calculated by multiplying its square footage by $0.073.

The mortgage analysis used a 30-year fixed mortgage period with a constant interest rate of 4.25% for all six counties. The mortgage analysis was performed on each county using the median values of home cost and added LEED cost calculated in the descriptive statistical analysis, and the cost of living index utility cost. The total fixed mortgage monthly payment was calculated using Equation 1. The 30-year mortgage analysis was performed comparing the traditional home to the LEED Certified level using a 15% down payment.

The utility cost for the 30-year mortgage period used the national average monthly utility cost and a cost of living index. The national average utility cost was $163 in 2011 (Wheeland, 2012). Accounting for inflation, the national monthly utility cost in 2013 translates to $169.58. The cost of living index used uses the national average at 100 and assigns locations a score either greater or less than 100, representing that locations' utility costs in relation to the national average (bestplaces.net 2012). For this study the cost of living index score for each county was expresses as a percent then multiplied by $168.58, yielding a utility cost unique to each county.

Table 1: Sample Data Population for the Selected Counties of Kentucky

Data Population for Selected Counties of Kentucky							
Fayette County		Jefferson County		Northern Kentucky		Spencer County	
Home Cost ($)	Square Feet	Home Cost ($)	Square Feet	Home Cost ($)	Square Feet	Home Cost ($)	Square Feet
169300	1950	188400	2365	181000	2200	199000	1444
183200	2181	197354	2018	181900	2149	160000	1370
188842	1855	197696	2200	205990	2160	160000	1300
191950	1976	205900	1886	224900	2357	209300	1602
196679	2423	208000	2198	224900	2365	179900	1362
198243	1853	210000	2086	230195	2197	169900	1362
205433	2274	217900	2101	262900	2367	200847	2016
208908	1938	218870	1960	194990	2200	219900	2451
229900	2551	223041	1886	199000	1738	159900	1800
233248	1938	224900	2140	192000	1775	143558	1135
239900	2456	233765	2101	189900	1741	209000	2086
239900	2265	239900	2010	234900	2357	201000	2240
245640	2127	254500	2221	294900	2776	216900	2464
249500	2005	305600	2715	199000	1931	204500	1828
263860	2410	140000	2770	262900	2367	199900	2016
268280	2464	237900	1860	182990	1883	194500	1725
269000	1804	230948	2997	192000	1715	245900	2243
269900	2100	305600	2715	235990	2160	174900	2066
280900	2300	325587	2997	228131	1865	162950	1724
291500	2397	388696	2921	239900	2105	166000	1727
312178	2465	399900	2456				
313872	2884	239900	1896				
	211330	2300					
	350000	2292					
	299900	2232					
	234755	2100					

$$EMI = \frac{(P*r)*(1+\frac{r}{12})^n}{(1+\frac{r}{12})^n-1} \quad \text{(2)}$$

P = principal barrowed amount

r = annual interest rate

n = number of monthly payments

EMI = fixed monthly payment

Figure 1 is a graphical representation of the median new construction home cost in the four county areas stated above. In Figure 1 it is shown that Fayette and Jefferson County have similar new construction home costs. It is also shown that Fayette County has the highest cost of new construction single-family homes and Spencer County has the lowest cost of new construction single-family homes.

Figure 2 shows the median square footage of the four areas. Figure 2 shows that Northern Kentucky was similar in square footage despite having a considerably lower median home cost. The relationship between home cost and square footage in northern Kentucky translates to a higher cost per square foot than the other areas studied. Spencer County was the most rural area as the other three areas are more representative

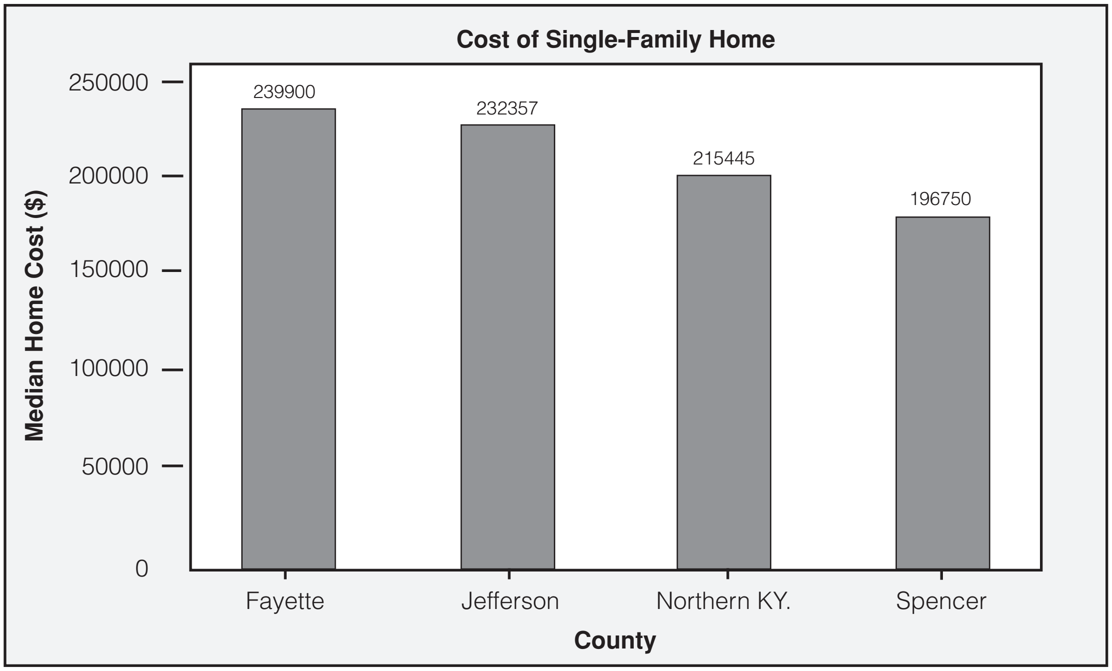

Figure 1. Comparison of the median home list prices of the selected counties of Kentucky (Northern KY refers to Boone, Cambell, and Kenton Counties)

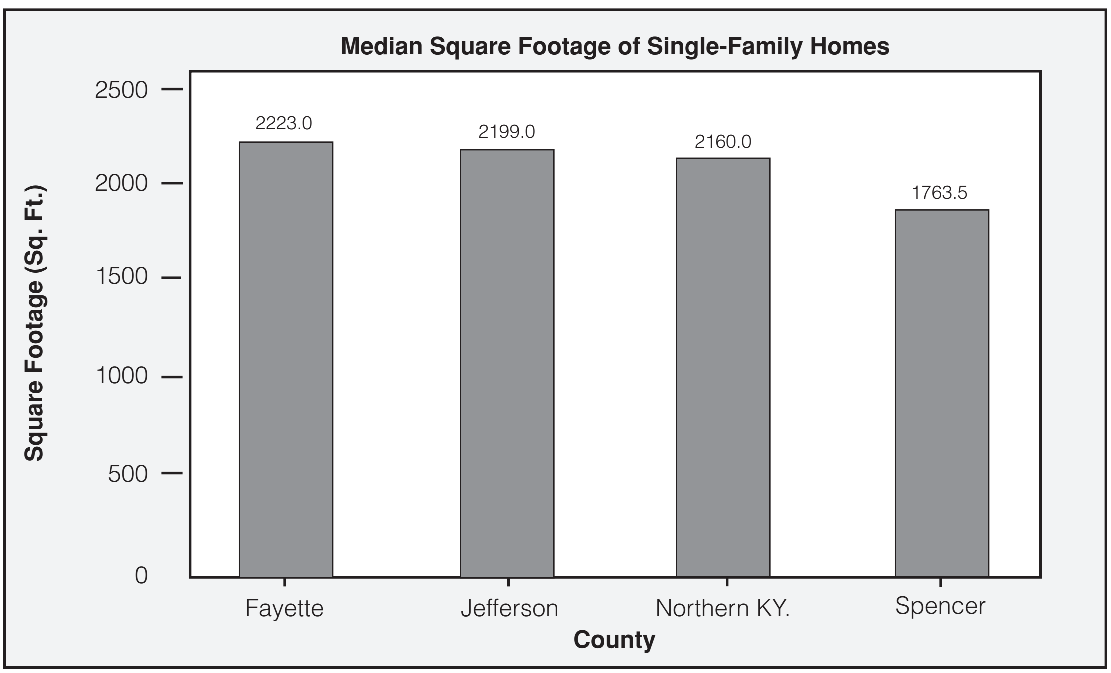

Figure 2. Median square footage of a new construction single-family home in all four counties.

of metropolitan areas. The rural nature of Spencer County is most likely the cause for the lower home cost and square footage.

Figure 3 shows the added construction cost for each LEED level in each county. As stated above the added LEED cost between levels in an individual county was proportional. This is because the LEED cost for the four levels for one home was estimated using a percentage from the list price of that home. However, there is some variability in added LEED construction cost. It is important to note that based on the percentages used in this study the added construction cost for the LEED Certified level are minimal, ranging from nearly $5,000.00 to just under $6,000.00.

Figure 4 shows the payback periods in years for each LEED level in each county. A significant finding shown in Figure 4 is that all four counties the LEED Certified level had a payback period between 19 and 21 years. The importance of this finding is that it shows the initial added construction cost associated with the LEED certification will be paid back before a typical 30 year mortgage period ends based solely on utility cost savings. Northern Kentucky and Spencer County were the only areas that a LEED Gold level home had payback period of less than 30 years. This is due to a lower median home cost and because the LEED cost was calculated using a percentage of the list price it resulted in a slightly lower added LEED cost than Fayette and Jefferson County. It is important to note that the LEED utility reduction percentages were conservative estimates and in actuality the efficiency may be greater than stated in this study.

The square footage of LEED certified home is a more significant factor in determining the payback period than the LEED reduction in utility cost. This is evident when comparing Jefferson and Spencer County. Jefferson County had the highest monthly utility cost resulting in the greatest LEED utility cost reduction of the four counties, but Spencer County had the smallest median square footage of the four counties. As seen in Figure 4, Spencer County had the shortest payback period for all four LEED levels, although Northern Kentucky had very similar results to Spencer County. The payback period for each LEED level was very similar among all four counties used in this study. Under the conditions of this study the location of the LEED-certified single-family home does not seem to be a significant factor in the payback period. However, it is important to consider the communication and multiple inspections by the green rater. The cost pertaining to proximity to these organizations was not considered in this study but could potentially be another aspect of the LEED costs in which case should be factored into the soft costs associated with LEED certification.

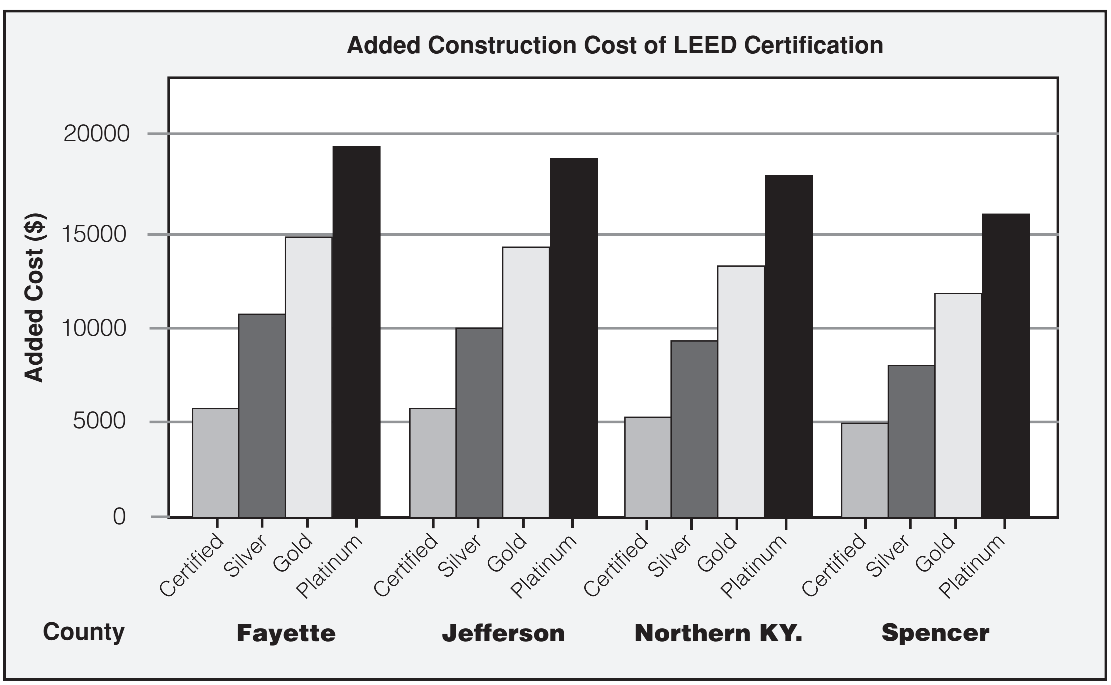

Figure 3: Comparison of the added construction cost for the four LEED levels in each county.

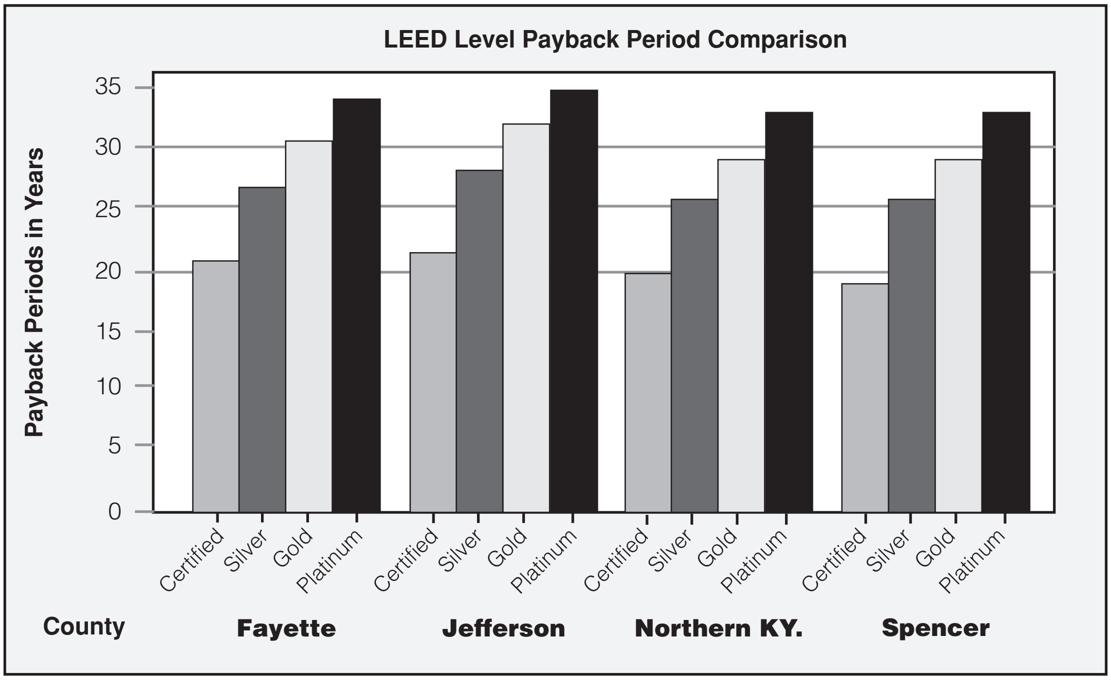

Figure 4. Comparison of the estimated payback period for the four LEED levels in each county.

Figure 5 shows the total 30 year cost net difference for a fixed 30-year mortgage period using a 15% down payment, with an interest rate of 4.25% for a traditional home and a LEED Certified level home in each county. The 30-year total cost is comprised of the total amount paid over the 30-year mortgage period (not including the down payment) and the total utility cost over the 30-year mortgage period.

Figure 5 is a comparison of the total 30-year costs based on the median values of traditional home costs, the added LEED Certified cost, and the cost of living index utility costs. Figure 5 shows that Jefferson and Spencer County produced a net gain, but Fayette County and Northern Kentucky produced a net loss over the 30-year mortgage period. Though the net gain or loss was small, especially considering it is over the course of a 30-year period. Under the conditions of this study, the added cost of construction associated with LEED certification does not produce a significant net cost over a traditional home during a typical 30-year mortgage period. The two counties with the greatest monthly utility cost are the two counties that produced a positive gain. These results show the utility cost of a specific area is a very significant factor in determining the cost effectiveness of LEED certified single-family homes. The importance of this finding is it showed that there is little difference, financially, between traditional homes compared to LEED Certified level homes. It is important to note that the 30-year total is based solely on added construction costs and utility efficiency.

Recommendations:

Sustainable design will continue increase in acceptance and become the standard for building new construction projects, both commercial and residential. The rising cost of utilities and the increasing concern of environmental impact are the two main factors pushing the industry toward building LEED certified. This study focused on providing the general public of Kentucky with information regarding the relationship between the expected added cost of building LEED and the expected utility savings that is associated with the various LEED levels.

This study found that the costs of the LEED Certified level to be minimal; the average of the median values was just under $5,500 for all four counties. The LEED level the reported the highest added cost was the LEED Platinum level in Fayette County at just over $19,000. A significant finding from the pay period analysis was that all the LEED Certified level single-family homes had a payback period between 19 and 21 years. Another finding was that the LEED Gold level payback periods were very close to the 30-year period, ranging from

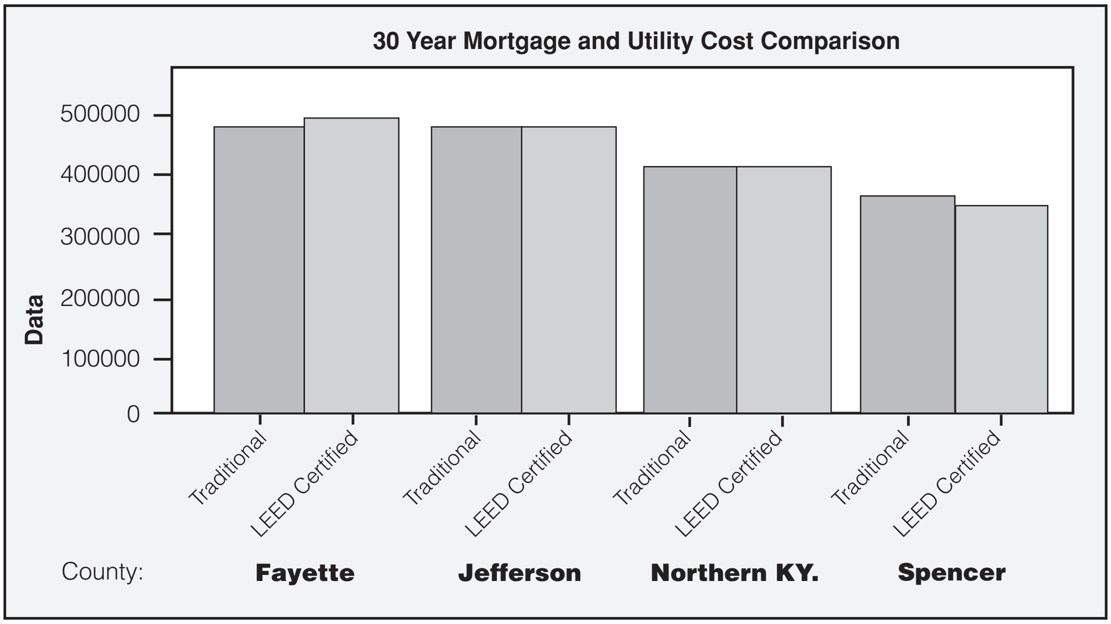

Figure 5. Comparison of the total 30-year mortgage cost using a 15% down payment, and a 4.25% interest rate.

29.5 to 31.5 years. The payback period for the LEED Platinum level was slightly longer than the Gold level by a margin of at most 4 years. The results from the economic analysis were very significant in that the greatest net loss was only \$1,200.00 and the greatest net gain was \$1,700.00. This is significant because it shows that over the course of 30-year mortgage period the added construction cost LEED certification is essentially negligible.

This study has shown that individuals considering building an LEED certified single-family home under the conditions used in this study in Fayette, Jefferson, Boone, Kenton, Campbell, or Spencer County that (a) The LEED Certified and Silver levels added construction cost have pay back periods less than 30 years and (b) if a 30-year fixed mortgage is used, the overall added construction cost for a certified-level single-family home is minimal. Based on the findings from this study, the following recommendations were made:

1. It is recommended that the legislators and policymakers of Kentucky develop some type of state and municipal tax credits that make building LEED certified homes more financially appealing to both home owners and homebuilders. A case study of municipal tax credits supporting LEED certification is the city of Cincinnati, OH. The tax incentive is 100% property tax abatement for 15 years for building a new construction LEED-certified home (DSIRE.org, 2013). As stated previously in this study Ohio has a total of 318 LEED certified single-family homes and 49% of those homes are in Cincinnati (USGBC, 2014).
2. It is suggested that the banking industry provide lower interest rates on mortgage loans to those building LEED-certified homes. As shown in the 30 year mortgage analysis portion of this study, a traditional home and LEED Certified level home using a an identical down payment and interest rate had very minimal difference in total cost between the two homes. A lower interest rate given to those building a LEED-certified home would directly aid in offsetting the added soft and construction costs of building LEED certified homes in Kentucky.

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Military and National Security Implications of Nanotechnology

By Jitendra S. Tate, Sergio Espinoza, Davontae Habbit, Craig Hanks, Walt Trybula, and Dominick Fazarro

ABSTRACT

All branches of the U.S. military are currently conducting nanotechnology research, including the Defense Advanced Research Projects Agency (DARPA), Office of Naval Research (ONR), Army Research Office (ARO), and Air Force Office of Scientific Research (AFOSR). The United States is currently the leader of the development of nanotechnology-based applications for military and national defense. Advancements in nanotechnology are intended to revolutionize modern warfare with the development of applications such as nano-sensors, artificial intelligence, nanomanufacturing, and nanorobotics. Capabilities of this technology include providing soldiers with stronger and lighter battle suits, using nano-enabled medicines for curing field wounds, and producing silver-packed foods with decreased spoiling rate (Tiwari, A., Military Nanotechnology, 2004). Although the improvements in nanotechnology hold great promise, this technology has the potential to pose some risks. This article addresses a few of the more recent, rapidly evolving, and cutting edge developments for defense purposes. To prevent irreversible damages, regulatory measures must be taken in the advancement of dangerous technological developments implementing nanotechnology. The article introduces recent efforts in awareness of the societal implications of military and national security nanotechnology as well as recommendations for national leaders.

Keywords: Nanotechnology, Implications, modern warfare

INTRODUCTION

Advances in nano-science and nanotechnology promise to have major implications for advances in the scientific field as well as peace for the upcoming decades. This will lead to dramatic changes in the way that material, medicine, surveillance, and sustainable energy technology are understood and created. Significant breakthroughs are expected in human organ engineering, assembly of atoms and molecules, and the emergence of a new era of physics and chemistry. Tomorrow's soldiers will have many challenges such as carrying self-guided missiles, jumping over large obstacles, monitoring vital signs, and working longer periods with sleep deprivation. (Altmann & Gubrud, Anticipating military nanotechnology, 2004). This will be achieved by controlling matter at the nanoscale (1-100nm). A nanometer is one-billionth of a meter. This article considers the social impact of nanotechnology (NT) from the point of view of the possible military applications and their implications for national defense and arms control. This technological evolution may become disruptive; meaning that it will come out of mainstream. Ideas that are coming forth through nanotechnology are becoming very popular and the possibilities will in practice have profound implications for military affairs as well as relations between nations and thinking about war and national security (Altmann J. , Military Uses of Nanotechnology: Perspectives and Concerns, 2004). In this article some of the potential applicability uses of recent nanotechnology driven applications within the military are introduced. This article also discusses how the impact of a rapid technological evolution in the military will have implications on society.

POTENTIAL MILITARY TECHNOLOGIES

Magneto rheological Fluid (MR Fluid)

A magneto-rheological-fluid is a fluid where colloidal ferrofluids experience a body force on the entire material that is proportional to the magnetic field strength (Ashour, Rogers, & Kordonsky, 1996). This allows the status of the fluid to change reversibly from a liquid to solid state. Thus, the fluid becomes intelligently controllable using the magnetic field. MR fluid consists of a basic fluid, ferromagnetic particles, and stabilizing additives (Olabi & Grunwald, 2007). The ferromagnetic particles are typically 20-50μm in diameter whereas in the presence of the magnetic field, the particles align and form linear chains parallel to the field

(Ahmadian & Norris, 2008). Response times that require impressively low voltages are being developed. Recently, (Ahmadian & Norris, 2008) has shown the ability of MR fluids to handle impulse loads and an adaptable fixing for blast resistant and structural membranes. For military applications, the strength of the armor will depend on the composition of the fluid. Researchers propose wiring the armor with tiny circuits. While current is applied through the wires, the armor would stiffen, and while the current is turned off, the armor would revert to its liquid, flexible state. Depending on the type of particles used, a variety of armor technology can be developed to adapt for soldiers in different types of battle conditions. Nanotechnology could increase the agility of soldiers. This could be accomplished by increasing mechanical properties as well as the flexibility for battle suit technology.

Nano Robotics

Nanorobotics is a new emerging field in which machines and robotic components are created at a scale at or close to that of a nanometer. The term has been heavily publicized through science fiction movies, especially the film industry, and has been growing in popularity. In the movie *Spiderman*, Peter Parker and Norman Osborn briefly talk about Norman's research which involves nanotechnology that is later used in the Green Goblin suit. Nanorobotics specifically refers to the nanotechnology engineering discipline or designing and building nano robots that are expected to be used in a military and space applications. The terms nanobots, nanoids, nanites, nanomachines or nanomites have been used to describe these devices but do not accurately represent the discipline. Nanorobotics includes a system at or below the micrometer range and is made of assemblies of nanoscale components with dimensions ranging from 1 to 100nm (Weir, Sierra, & Jones, 2005). Nanorobotics can generally be divided into two fields. The first area deals with the overall design and control of the robots at the nanoscale. Much of the research in this area is theoretical. The second area deals with the manipulation and/or assembly of nanoscale components with macroscale manipulators (Weir, Sierra, & Jones, 2005). Nanomanipulation and nanoassembly may play a critical role in the development and deployment of artificial robots that could be used for combat.

According to Mavroidis et al. (2013), nanorobots should have the following three characteristic abilities at the nano scale and in presence of a large number in a remote environment. First they should have swarm intelligence. Second the ability to self-assemble and replicate at the nanoscale. Third is the ability to have a nano to macro world interface architecture enabling instant access to the nanorobots with control and maintenance. (Mavroidis & Ferreira, 2013) also states that collaborative efforts between a variety of educational backgrounds will need to work together to achieve this common objective. Autonomous nanorobots for the battlefield will be able to move in all media such as water, air, and ground using propulsion principles known for larger systems. These systems include wheels, tracks, rotor blades, wings, and jets (Altmann & Gubrud, Military, arms control, and security aspects of nanotechnology, 2004). These robots will also be designed for specific military tasks such as reconnaissance, communication, target destination, and sensing capabilities. Self-assembling nanorobots could possibly act together in high numbers, blocking windows, putting abrasives into motors and other machines, and other unique tasks.

Artificial Intelligence

Artificial intelligence (AI) is a vast emerging field that can be very thought provoking. AI has been seen recently in a number of movies and television shows that have predicted what the possibility of an advanced intelligence could do to our society. This intellect could possibly outperform human capabilities in practically every field from scientific research to social interactions. Aspirations to surpass human capabilities include tennis, baseball, and other daily tasks demanding motion and common sense reasoning (Kurzweil, 2005). Examples where AI could be seen include chess playing, theorem proving, face and speech recognition, and natural language understanding. AI has been an active and dynamic field of research and development since its establishment in 1956 at the Dartmouth Conference in the United States (Cantu-Ortiz, 2014). In past decades, this has led to the development of smart systems, including phones, laptops, medical instruments, and navigation software.

One problem with AI is that people are coming to a conclusion about its capabilities too soon. Thus, people are becoming afraid of the probability that an artificial intelligent system could possibly expand and turn on the human race. True artificial intelligence is still very far from becoming "alive" due to our current technology.

Nanotechnology might advance AI research and development. In nanotechnology, there is a combination of physics, chemistry and engineering. AI relies most heavily on biological influence as seen genetic algorithm mutations, rather than chemistry or engineering. Bringing together nanosciences and AI can boost a whole new generation of information and communication technologies that will impact our society. This could be accomplished by successful convergences between technology and biology (Sacha & P., 2013). Computational power could be exponentially increased in current successful AI based military decision behavior models as seen in the following examples.

Expert Systems

Artificial intelligence is currently being used and evolving in expert systems (ES). An ES is an "intelligent computer program that uses knowledge and interference procedures to solve problems that are difficult enough to require significant human expertize to their solution" (Mellit & Kalogirou, 2008). Results early on in its development have shown that this technology can play a significant impact in military applications. Weapon systems, surveillance, and complex information have created numerous complications for military personnel. AI and ES can aid commanders in making decisions faster than before in spite of limitations on manpower and training. The field of expert systems in the military is still a long way from solving the most persistent problems, but early on research demonstrated that this technology could offer great hope and promise (Franklin, Carmody, Keller, Levitt, & Buteau, 1988). Mellit et al. argues that an ES is not a program but a system. This is because the program contains a variety of different components such as a knowledge base, interference mechanisms, and explanation facilities. Therefore they have been built to solve a range of problems that can be beneficial to military applications. This includes the prediction of a given situation, planning which can aid in devising a sequence of actions that will achieve a set goal, and debugging and repair-prescribing remedies for malfunctions.

Genetic Algorithms

Artificial intelligence with genetic algorithms (GA) can tackle complex problems through the process of initialization, selection, crossover, and mutation. A GA repeatedly modifies a population of artificial structures in order to adjust for a specific problem (Prelipcean et al., 2010). In this population, chromosomes evolve over a number of generations through the application of genetic operations. This evolution process of the GA allows for the most elite chromosomes to survive and mate from one generation to the next. Generally, the GA will include three genetic operations of selection, crossover, and mutation. This is currently being applied to solving problems in military vehicle scheduling at logistic distribution centers.

Nanomanufacturing

Nanomanufacturing is the production of materials and components with nanoscale features that can span a wide range of unique capabilities. At the nanoscale, matter is manufactured at lengthscales of 1-100nm with precise size and control. The manufacturing of parts can be done with the "bottom up" from nano sized materials or "top down" process for high precision. Manufacturing at the nanoscale could produce new features, functional capabilities, and multi-functional properties. Nanomanufacturing is distinguished from nanoprocessing, and nanofabrication, whereas nanomanufacturing must address scalability, reliability and cost effectiveness (Cooper & Ralph, 2011). Military applications will need to be very tough and sturdy but at the same time very reliable for use in harsh environments with the extreme temperatures, pressure, humidity, radiation, etc. The use of nano enabled materials and components increase the military's in-mission success. Eventually, these new nanotechnologies will be transferred for commercial and public use. Cooper et al. makes known how nanomanufacuring is a multi-disciplinary effort that involves synthesis, processing and fabrication. There are however a great number of challenges that as well as opportunities in nanomanufacturing R&D such as;

- Predictions from first principles of the progress and kinetics of nanosynthesis and nano-assembly processes.

- Understand and control the nucleation and growth of nanomaterial and nanostructures and asses the effects of catalysts, crystal orientation, chemistry, etc. on growth rates and morphologies.

R&D IN THE USA

The USA is proving to have a lead in military research and development in nanotechnology. Research spans under umbrella of applications related to defense capabilities. NNI has provided funds in which one quarter to one third goes to the department of defense – in 2003, $ 243 million of $774 million. This is far more than any country and the US expenditure would be five times the sum of all the rest of the world (Altmann & Gubrud, Military, arms control, and security aspects of nanotechnology, 2004).

INITIATIVES

The National Nanotechnology Initiative

The National Nanotechnology Initiative (NNI) was unveiled by President Clinton in a speech that he gave on science and technology policy in January of 2000 where he called for an initiative with funding levels around 500 million dollars (Roco & Bainbridge, 2001). The initiative had five elements. The first was to increase support for fundamental research. The second was to pursue a set of grand challenges. The third was to support a series of centers of excellence. The fourth was to increase support for research infrastructure. The fifth is to think about the ethical, economic, legal and social implications and to address the education and training of nanotechnology workforce (Roco & Bainbridge, 2001). NNI brings together the expertise needed to advance the potential of nanotechnology across the nation.

ISN at MIT

The Institute for Soldier Nanotechnologies (ISN) initiated at the Massachusetts Institute of Technology in 2002 (Bennet-Woods, 2008). The mission of ISN is to develop battle-suit technology that will increase soldier survivability, protection, and create new methods of detecting toxic agents, enhancing situational awareness, while decreasing battle suit weight and increasing flexibility.

ISN research is organized into five strategic areas (SRA) designed to address broad strategic challenges facing soldiers. The first is developing lightweight, multifunctional nanostructured materials. Here nanotechnology is being used to develop soldier protective capabilities such as sensing, night vision, communication, and visible management. Second is soldier medicine – prevention, diagnostics, and far-forward care. This SRA will focus on research that would enable devices to aid casualty care for soldiers on the battle field. Devices would be activated by qualified personnel, the soldier, or autonomous. Eventually, these devices will find applications in medical hospitals as well. Third is blast and ballistic threats – materials damage, injury mechanisms, and lightweight protection. This research will focus on the development of materials that will provide for better protection against many forms of mechanical energy in the battle field. New protective material design will decrease the soldier’s risk of trauma, casualty, and other related injuries. The fourth SRA is hazardous substances sensing. This research will focus on exploring advanced methods of molecularly complicated hazardous substances that could be dangerous to soldiers. This would include food-borne pathogens, explosives, viruses and bacteria. The fifth and final is nanosystems integration –flexible capabilities in complex environments. This research focuses on the integration of nano-enabled materials and devices into systems that will give the soldier agility to operate in different environments. This will be through capabilities to sense toxic chemicals, pressure, and temperature, and allow groups of soldiers to communicate undetected (Institute for Soldier Nanotechnologies).

SOCIAL IMPLICATIONS

The purpose of country’s armed forces is to provide protection from foreign threats and from internal conflict. On the other hand, they may also harm a society by engaging in counter-productive warfare or serving as an economic burden. Expenditures on science and technology to develop weapons and systems sometimes produces side benefits, such as new medicines, technologies, or materials. Being ahead in military technology provides an important advantage in armed conflict. Thus, all potential opponents have a strong motive for military research and development. From the perspective of international security and arms control it appears that in depth studies of the social science of these implications has hardly begun. Warnings about this emerging technology have been sounded against excessive promises made too soon. The public may be too caught up with a “nanohype” (Gubrud & Altmann, 2002). It is essential to address questions of possible dangers arising from military use of nanotechnology and its impacts on national security. Their consequences need to be analyzed.

NT and Preventative Arms Control

Background

The goal of preventive arms control is to limit how the development of future weapons could create horrific situations, as seen in the past world wars. A qualitative method here is to design boundaries which could limit the creation of new military technologies before they are ever deployed or even thought of. One criterion regards arms control and how the development of military and surveillance technologies could go beyond the limits of international law warfare and control agreements. This could include autonomous fighting war machines failing to define combatants of either side and Biological weapons could possibly give terrorist circumvention over existing treaties (Altmann & Gubrud, Military, arms control, and security aspects of nanotechnology, 2004). The second criterion is to prevent destabilization of the military situation which emerging technologies could make response times in battle much faster. Who will strike first? The third criterion, according to Altman & Gubrud, is how to consider unintended hazards to humans, the environment, and society. Nanoscience is paving the way for smaller more efficient systems which could leak into civilian sectors that could bring risks to human health and personal data. Concrete data on how this will affect humans or the environment is still uncertain.

Arms Control Agreements

The development of smaller chemical or biological weapons that may contain less to no metal could potentially violate existing international laws of warfare by becoming virtually undetectable. Smaller weapons could fall into categories that would undermine peace treaties. The manipulation of these weapons by terrorist could give a better opportunity to select specific targets for assassination. Anti-satellite attacks by smaller more autonomous satellites could potentially destabilize the space situation. Therefore a comprehensive ban on space weapons should be established (Altmann & Gubrud, 2002). Autonomous robots with a degree of artificial intelligence will potentially bring great problems. The ability to identify a soldiers current situation such as a plea for surrender, a call for medical attention, or illness is a a very complicated tasks that to an extent requires human intelligence. This could potentially violate humanitarian law.

Stability

New weapons could pressure the military to prevent attacks by pursuing the development of new technologies faster. This could lead to an arms race with other nations trying to attain the same goal. Destabilization may occur through faster action, and more available nano systems. Vehicles will become much lighter and will be used for surveillance. This will significantly reduce time to acquire a targets location. Medical devices implanted in soldiers’ bodies will enable the release of drugs that influence mood and response times. For example, an implant that attaches to the brains nervous system could give the possibility to reduce reaction time by processing information much faster than usual (Altmann & Gubrud, Anticipating military nanotechnology, 2004). Artificial intelligence based genetic algorithms could make tactical decisions much faster through computational power by adapting to a situations decision. Nano robots could eavesdrop, manipulate or even destroy targets while at the same time being undetected (Altmann J. , Military Uses of Nanotechnology: Perspectives and Concerns, 2004).

Environment Society & Humans

Human beings have always been exposed to natural reoccurring nanomaterials in nature. These particles may enter the human body through respiration, and ingestion (Bennet-Woods, 2008). Little been known about how manufactured nanoscale materials will have an impact to the environment. Jerome (2005) argues that nanomaterials used for military uniforms could break of and enter the body and environment. New materials could destroy species of plants and animal. Fumes from fuel additives could be inhaled by military personnel. Contaminant due to weapon blasts could lead to diseases such as cancer or leukemia due to absorption through the skin or inhalation.

Improper disposal of batteries using nano particles could also affect a wide variety of species. An increase in nanoparticle release into the environment could be aided by waste streams from military research facilities. Advanced nuclear weapons that are miniaturized may leave large areas of soil contaminated with radioactive materials. There is an increase in toxicity as the particle size decrease which could cause unknown environmental changes. Bennet-woods (2008) argues that there is great uncertainty in which the way nano materials will degrade under natural conditions and interact with local organisms in the environment.

Danger to society could greatly be affected due to self-replicating, mutating, mechanical or biological plagues. In the event that these intelligent nano systems were to be unleashed, they could potentially attack the physical world. There are a number of applications that will be developed with nanotechnology that could potentially crossover from the military to national security that can harm the civilian sector (Bennet-Woods, 2008). There is a heightened awareness that new technologies will allow for a more efficient access to personal privacy and autonomy (Roco & Bainbridge, 2005). Concerns regarding artificial intelligence acquiring a vast amount of personal data, voice recognition, and financial data will also arise. Implantable brain devices, intended for communication, raise concerns for actually observing and manipulating thoughts. Some of the most feared risks due to nanotechnology in the society are the loss of privacy (Flagg, 2005). Nano sensors developed for the battlefield could be used for eavesdropping and tracking of citizens by state agencies. This could lead to improvised warfare or terrorism. Bennet-Woods (2008) argues that there should be an outright ban on nanoenabled tracking and surveillance devices for any purpose.

Nanotechnology in combination with biotechnology and medicine raise concerns regarding human safety. This includes nanoscale drugs that may allow for improvements in terrorism alongside more efficient soldiers for combat. Bioterrorism could greatly be improved through nano-engineered drugs and chemicals (Milleson, 2013). Body implants could be used by soldiers to provide for better fighting efficiency but in the society, the extent in which the availability of body manipulation will have to be debated at large (Altmann J. , Nanotechnology and preventive arms control, 2005). Brain implanted stimulates could become addictive and lead to health defects. The availability of body and brain implants could have negative effects during peace time. Milleson (2013) argues that there is fear that this technology could destabilize the human race, society, and family. Thus, the use in society should be delayed for at least a decade.

CONCLUSIONS

Nanoscience will lead to a revolutionary development of new materials, medicine, surveillance, and sustainable energy. Many applications could arrive in the next decade. The US is currently in the lead in nanoscience research and development. This equates to roughly five times the sum of all the rest of world. It is essential to address the potential risks that cutting edge military applications will have on warfare and civilian sector. There is a potential for mistrust in areas where revolutionary changes are expected. There are many initiatives by federal agencies, industry, and academic institutions pertaining to nanotechnology applications in military and national security. Preventive measures should be coordinated early on among national leaders. Scientists propose for national leaders to follow general guidelines. There shall be no circumvention of existing treaties as well as a ban on space weapons. Autonomous robots should be greatly restricted. Due to rapidly advancing capabilities, a technological arms race should be prevented at all costs. Nanomaterials could greatly harm humans and their environment therefore nations should work together to address safety protocols. The national nanotechnology of different nations should build confidence in addressing the social implications and preventive arms control from this technological revolution.

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Adopting Mobile Technology in the Higher Education Classroom

By Christopher B. Davison and Edward J. Lazaros

ABSTRACT

Mobile technologies have become inexpensive and ubiquitous. This has led to the proliferation of mobile technologies being employed by students for mobile learning (mLearning) purposes. Preferences for mLearning technologies among a higher education student population at a mid-sized Indiana research and teaching university are explored in this article. The findings of this research are compared to similar research from several years prior conducted by Conole, Laat, Dillon, and Darby, 2006. This comparison yielded some interesting findings such as students in both studies strongly agreeing that mLearning is an important aspect of their coursework. Other interesting findings include the laptop remaining as a preferred student technology, and the discussion board gaining in popularity among the U.S. population when compared to their U.K. counterparts in the Conole et al. (2006) study. Opportunities for future research relating to mLearning still remain and are described in this article.

Keywords: mLearning, mobile technology, mobile learning, discussion boards, technology adoption, educational technology.

INTRODUCTION

The utilization of mobile learning (mLearning) technology is an increasing trend in the higher education setting (Mansureh, 2010). El-Hussein and Cronje (2010) defined mLearning as "any type of learning that takes place in learning environments and spaces that take account of the mobility of technology, mobility of learners and mobility of learning" (p. 20). In this article, the findings that resulted from a study of students' use and experiences with mobile technologies are presented. A higher education student population at a mid-sized Indiana research and teaching university was surveyed, and the results were statistically analyzed. The results of this study were compared to a similar study (upon which this one is based) of British students (Conole, Laat, Dillon, & Darby, 2006). The findings suggest that students employ a number of mLearning technologies, and they have a consistent preference for laptops, which they use during their course of studies. The U.S. students demonstrated similar attitudes and preferences to their British counterparts who were surveyed six years earlier. However, student preferences for the Discussion Board, as an online facility, were notably different across studies.

RESEARCH PROBLEM STATEMENT

There is a great deal of research that examines mobile technology adoption within higher education. Conole et al. (2006) investigated U.K. students' utilization of experiences with technologies. Respondents answered questions that were both qualitative (in-depth interviews) and quantitative (via a survey). This current research serves to replicate the quantitative portion in the USA with minor adjustments to fit a web-based delivery system.

The problem is twofold in nature: (a) This research on the use of both mobile and smartphone technology within the higher education classroom tends to be geographically bounded, and (b) there is little longitudinal work in this area. This article adds to the body of scientific knowledge on mLearning in that it is a geographically bounded (i.e., a mid-sized, east-central Indiana research and teaching university) research study. Furthermore, it expounds upon the Conole et al. (2006) study, from several years prior, and compares the new data to that study.

LITERATURE REVIEW

There is a great deal of research and information addressing technology infusion into the classroom across all grade levels from K-12 to the university setting. However, these studies report mixed results of effectiveness, but overall, the trend continues to support an increase in adopting mobile technology within the higher education classroom environment (Mansureh, 2010). Emerging technologies revolutionize the way students and faculty members communicate and interact with each other (Hirumi, 2014). The literature indicates that mLearning technologies have the potential to facilitate learning in a pedagogical environment (Patten, Sanchez, & Tangney, 2006).

Mobile learning can be used in place of having a computer in every home, and it can allow for greater freedom, because the learning material can be accessed from anywhere. Hardware and software are advancing rapidly enough that accessing learning content on a mobile device has no downside when comparing it to accessing the content on a computer (Shao & Seif, 2014, p. 3). mLearning can engage students in active learning that can lead to the development of critical thinking and problem solving skills. Mobile learning allows students to do hands-on learning and combine it with traditional course material (Granić, Ćukušić, & Walker, 2009, p. 170).

There are other positive aspects of using mLearning. Students that are able to interact with the course using mLearning are likely to have fun and enjoy the course, and they pursue the content that they find the most interesting. mLearning allows students to work at their own pace, in the environment that is the most comfortable to them (Granić, Ćukušić, & Walker, 2009, p. 180). These technologies represent a shift from knowledge procurement to a more interactive form of learning (Conole, 2007). Furthermore, these technologies can foster "self-regulation" (Beishuizen, 2008, p. 183) within the student.

Prior to the implementation of mLearning, there are many considerations. For example, the content should be designed so that it works on the least advanced device, so that the largest range of students can access it (Wang & Shen, 2012, p. 567). It is also important for designers to use different techniques when designing mLearning to appeal to many types of learners (Wang & Shen, 2012, p. 570). Consideration needs to be given to the potential detriments to the learning process. Mobile technologies have the potential to facilitate non-learning activities in the classroom and serve as a distraction (Wood, De Pasquale, & Cruikshank, 2012). While mLearning technologies can have a positive impact on student learning, the technologies are not without issues.

Challenges pre-sentenced by mLearning technologies are instructor technology adoption as well as instructor facilitation of electronic learning (eLearning) platforms (Darby, 2004). A number of barriers to the adoption of technology exist in the educational environment. These barriers range from technical capabilities of the infrastructure to policy enactment (McKay, Seward, & Davison, 2014). Seminal research on the Technology Acceptance Model (TAM) in the education sector indicates that the highest determinant of adoption is the perceived usefulness of the technology (Hu, Clark, & Ma, 2003).

The Conole, Latt, Dillion, and Darby et al. (2008) work informs researchers that students tend to select mobile technologies that enhance their learning style, and their choice is often a matter of trial and error. This study was one of the many studies funded by the U.K.'s Joint Information Systems Committee (JISC) as part of an ePedagogy program. The purpose of the program, and subsequently the Conole et al. (2006, 2008) works, was to understand learners' experiences with eLearning technologies. Their work was both quantitative and qualitative in nature, including in-depth interviews, case studies, and surveys. The research in this area was lacking because mLearning tools were relatively new at the time.

Conole et al. (2006) performed a quantitative, survey-based, study on the experiences and usage of technologies by students. The survey instrument from their work was used as the data collection instrument for this study. As in this study, the researchers sought to provide empirically grounded data on students' actual use and usage patterns of technologies. The focus of both studies is to examine how learners engage and experience both eLearning and mLearning technologies and how those technologies fit into the entire learning experience.

A definition of eLearning from eLearningNC.gov (2015) is given as "utilizing electronic technologies to access educational curriculum outside of a traditional classroom. In most cases, it refers to a course, program or degree delivered completely online" (para. 1). Even though mobile technology adoption is a continuing trend, the issues presented above create real barriers in adopting mobile technology in the classroom and facilitating eLearning. Coupled with implementation issues (e.g., budget, technology procurement, bandwidth, and support) faced by the organization (McKay, Seward, & Davison, 2014), mobile technology adoption is a difficult proposition. Despite the barriers that exist, mLearning is increasingly a part of campus life/education.

From the literature, it is found that mLearning is an increasing trend. As such, the authors of this article sought to discover the mLearning trends occurring at their home university. This study fits into the broader context of the literature from a geographic as well as a temporal perspective. The Conole et al. (2006) study was performed in the nascent stages of mLearning technologies and took place in the U.K. Even though mobile technology is still evolving, this study occurs at a point after which the technology has experienced some maturation and took place in the United States.

PURPOSE OF THE STUDY

The purpose of this quantitative cross-sectional survey study is to ascertain characteristics of use and adoption of both smartphone and mobile technology within a student population at a mid-sized Indiana research and teaching university. The data will be compared to data obtained by Conole et al. (2006) in their similar British study. A cross-section design was deemed appropriate, because it examines current practices, attitudes, beliefs, and opinions within a definitive group (Cresswell, 2005).

This study addresses the technological impact that mLearning has on pedagogy practice. The authors attempt to identify specific technologies and specific technology usage patterns. Such identification is important in order to assist educators in identifying and planning for mLearning technologies and incorporating those technologies into the classroom.

RESEARCH QUESTIONS

1. Are students utilizing smartphones and other technologies for their courses?
2. If yes: to what degree and how?
3. What technologies appear the most useful or preferred?
4. How are these technologies being utilized?

RESEARCH DESIGN AND METHODOLOGY

Subjects, Participation, and IRB

The survey population consisted of 20,503 graduate and undergraduate students at one mid-sized Indiana research and teaching university. Participants were recruited via mass campus email in the Fall of 2014. The entire population was surveyed. To be eligible to participate in the study, the students must have been over the age of 18. Sample participation (ratio of invites to participation) was .7 percent, with 148 electing to participate in the survey.

This study was cleared through the Ball State University IRB office. The study procedures were cleared as "Exempt" under federal regulations. The assigned protocol number is: 601429-1.

Measuring Instrument: Design and Procedure

Data was obtained through the use of an online questionnaire. The questionnaire was based on the eLearning Research Center (2013) work and slightly modified (see details that follow) for web-based delivery. The eLearning Research Center instrument contained a series of matrices of technologies against types of learning activities that was derived from the DialogPlus taxonomy (Canole, 2006). This served as a basis for the instrument as it is widely utilized and accepted as valid and reliable.

After slight modifications of the instrument to facilitate the Qualtrics system, a pilot test was performed. These modifications were only functional in nature, where a slider bar was added along with selection boxes as the original survey from Conole et al. (2006). Feedback from this test was then incorporated into the final, web-based survey instrument. The participants in the pilot test, while suggesting no major changes to the instruments, did generally agree on two areas where the instrument verbiage needed clarification. This was due in large part to the adaptation of a United Kingdom survey to American students. For example, the term "hall of residence" was changed to "dorm" for clarity purposes.

The second area of modification proved to be more significant after the data was collected and analyzed. The pilot test participants suggested adding another modality of communication: social media. As it turns out, this was a significant form of communications (see Results discussion) in many categories.

Following the pilot testing, the instrument was then implemented and delivered through the Qualtrics analytics system. The University Communications office was contacted and they agreed to deliver email solicitations to the student population inviting participation.

Implementation and Content

The study was carried out by surveying all students at a mid-sized Indiana research and teaching university. Participants were emailed an invitation to fill out a validated survey instrument and the results were statistically analyzed. The survey sample set (N) was 148. To answer the research questions, students were surveyed in three general categories relating to mLearning: digital technology usage, communication tool usage, and online learning facility usage. Next, the subjects were asked several questions regarding their attitude toward mLearning technologies. Finally, each student was asked to assess their technology usage in their studies as compared to their personal utilization of such. This information would be useful in answering research question number four relating to how technologies are being utilized.

RESULTS

Digital Technology Utilization

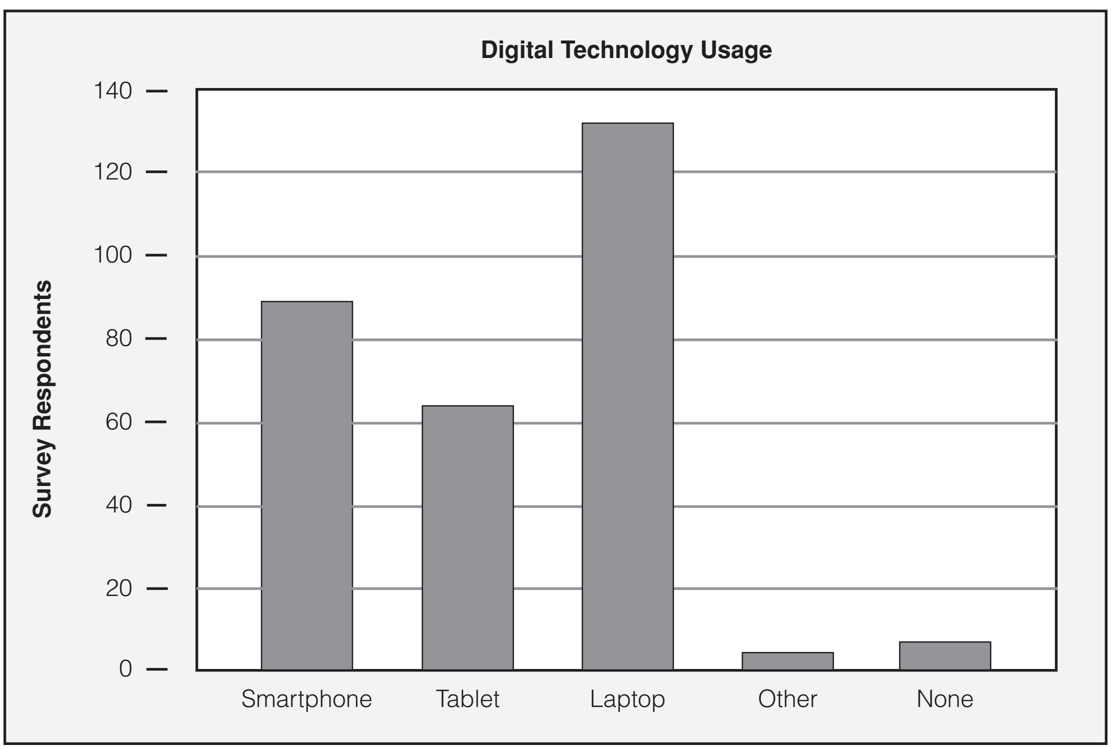
The respondents showed a larger preference for laptop utilization as an mLearning tool over all other technologies: almost 90 percent of the students used a laptop as an mLearning device. This was followed by 60 percent utilization rate for smart phones and then 45 percent for tablet devices. In every surveyed category of digital technology for studies, the laptop was favored. See Table 1 for a visual depiction of the digital technology survey results.

In this research, just over 70 percent of the students utilized more than one mLearning device, with many students possessing and utilizing three or more mLearning technologies. The data indicates that students utilize a wide variety of mLearning technologies to facilitate learning, while only three percent indicated they did not utilize any mLearning devices.

Interestingly, even for student to student communication the laptop, as a device, was favored over all other technologies including mobile phone texting. Comparatively, students preferred mobile phones as a digital technology (texting, calling) with friends and family over any other technology. Aside from personal communications, the laptop appears to be a ubiquitous and utilitarian mLearning tool.

These results from this research are similar to the Conole et al. (2006) study. In that research the laptop/desktop was the primary student-to-student communication tool. As in this study, the mobile phone was second. Similarly, as in this study, Canole et al. (2006) found mobile phones to be the primary digital technology for communications to family and friends, followed by the laptop/desktop (as in this study).

Table 1



Communication Tools Utilization

The most utilized method of communicating with other students was via email (85 percent of students use this method), followed by texting (65 percent). Communication with teachers/tutors was similar (see Table 2), with 88 percent of respondents communicating via email. With regard to personal communications, texting was the most used communication tool (85 percent) followed by voice calls at 74 percent. Email was a close third with 66 percent.

Email was also found to promote group collaboration. When asked about tools that promote group efforts such as task collaboration and task planning, 76 percent found that email did promote task collaboration. In this category, email was clearly preferred. The next ranked technology was texting at only 45 percent.

Email, in the Conole et al. (2006) study, was by far the most utilized communication tool. This was true for student to student, student to friend/family, and student to instructor communications. While their 2006 version of their instrument did not specify texting, it did specify instant messaging. In their study, instant messaging was the second largest category of student-to-student and student-to-friend/family communications tool. In this study, only 40 percent of the respondents selected instant messaging as a communications method with friends and family.

Online Learning Facilities

Online learning facilities are those facilities such as digital libraries, search engines, discussion boards, and virtual environments that are utilized for pedagogy. In this research study the Virtual Learning Environment (VLE) and, more specifically, the Discussion Board is the most utilized online learning facility in each category with the exception of friends/family communications. Students utilize these two facilities for everything from exam review to reading course materials. Search engines showed very high rankings in certain categories, such as information gathering (67 percent) and individual learning task performance (44 percent).

The preference for the VLE is congruent with the Conole et al. (2006) in the areas of exam review and course material delivery. In both studies, the VLE and search engines were popular. However, in this study, the Discussion Board was very highly favored, which is the opposite of the Conole et al. (2006) findings. In their study, the Discussion Board was utilized very little in almost every category, except for communications. Surprisingly, the Conole et al. (2006) study reports the Discussion Board being highly utilized in the communications with friends/family category. This study found only four reported instances of the Discussion Board being highly utilized by the students who responded to the survey instrument for the purposes of communicating with friends and family.

Table 2

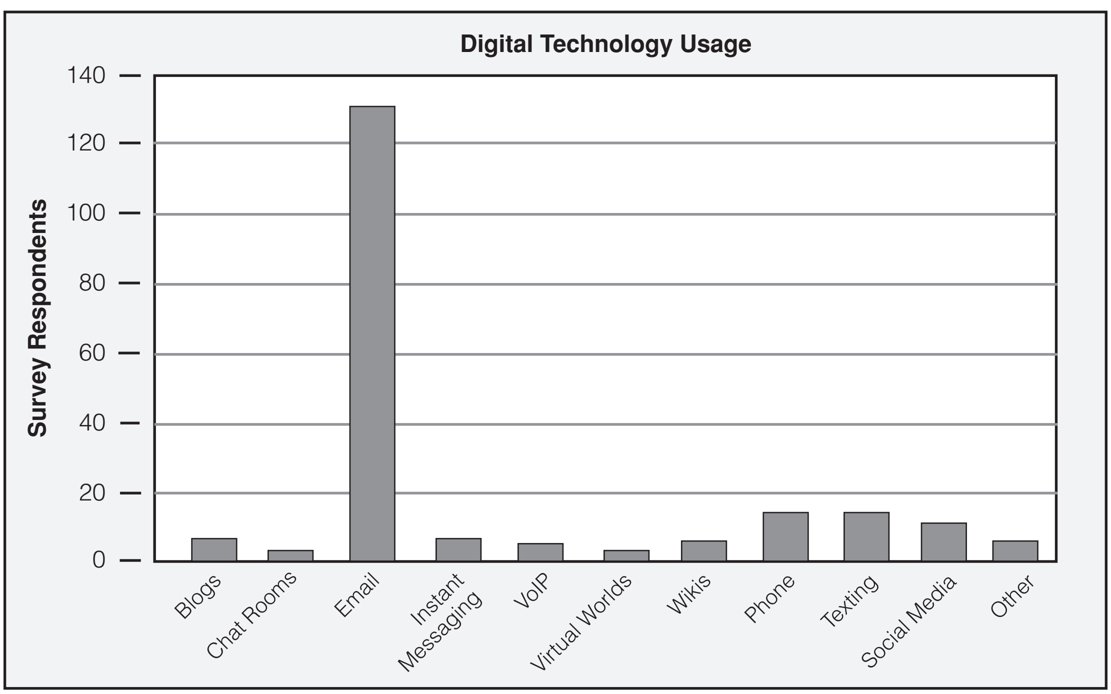
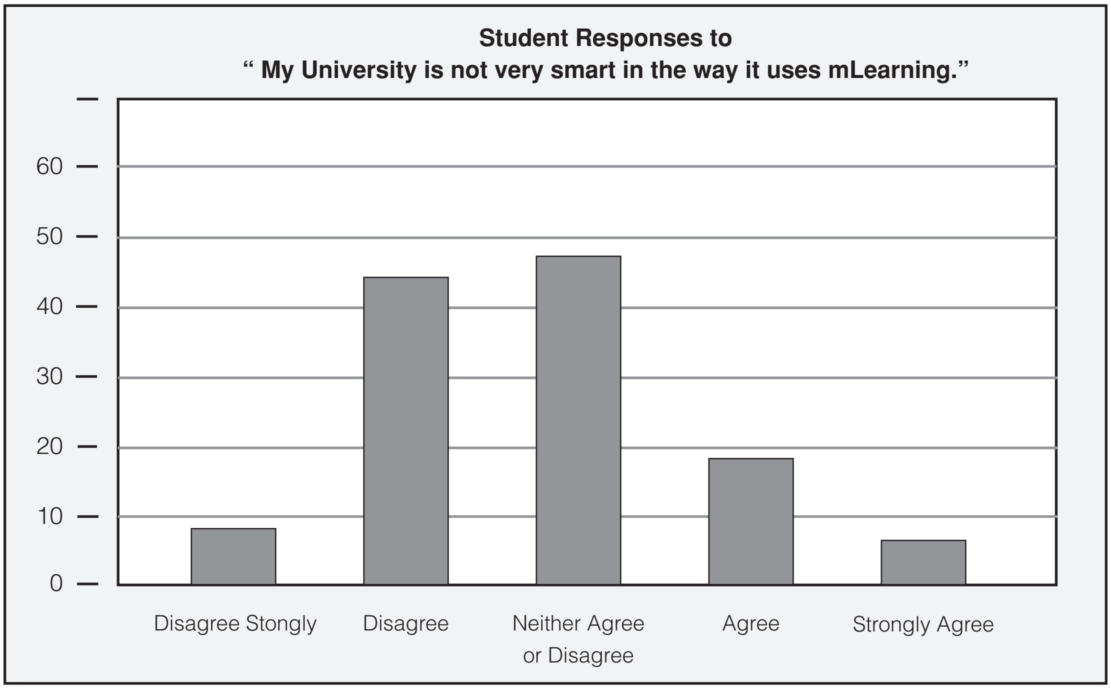


Table 3



Student Perceptions of mLearning Technologies
This section of the instrument, varies slightly from the wording in the Conole et al. (2006) study instrument. As those researchers were interested in eLearning overall, they utilized the term eLearning, while this study focused more narrowly in this section on mLearning. The operational definition provided in the instruments was comparable in each study: "any kind of Internet or communication service or electronic device that supports you in a learning activity."

In both studies, the students strongly agreed that eLearning/mLearning is an important aspect of their course work. Similarly, in both studies students were ambivalent with regard to eLearning/mLearning being crucial to their study capability. In the Conole et al. (2006), 18 percent of the students neither agreed nor disagreed that eLearning was crucial to their study capability. Respondents in this study neither agreed nor disagreed to that statement at a rate of 17 percent.

Most students agreed mLearning technology was an important element to making their course work more enjoyable. Conole et al. (2006) eloquently surmised this by stating that "…in general most of the students across the disciplines are responding rather positively towards eLearning in their courses and are quite neutral about how eLearning is being used within the institutions" (p. 76). The students responding to this survey were generally neutral when asked if their university was not very smart in the way it uses mLearning technology. The largest majority of respondents "neither agree nor disagree" with that statement, followed closely disagree" with that statement (see Table 3).

As expected, the students responding to this survey experienced little trouble finding Internet connected computers. The current study and Canole et al. (2006) indicated almost 50 percent of participants strongly disagreed with this statement. In both surveys, the next largest percentage was disagree with that statement (Conole et al. (2006) at 35 percent and this study at 31 percent). When asked if they had trouble utilizing technology or computers, most (77 percent) strongly disagreed or disagreed with that statement. Again, that is congruent with the Canole et al. (2006) survey.

Comparison to Previous Research
The results of this study are strikingly similar to the Conole et al. (2006) study. Separated by several years and a hemisphere, the students showed quite similar attitudes toward, and preferences in, mLearning technologies. Worthy of note is the absence of a tablet device in the Conole et al. (2006) research. The iPad and Galaxy Tab was not introduced until 2010, the Kindle in 2011, and the Surface was not available until 2012. In this research study, tablet devices did make a strong showing in every category: 45 percent of respondents indicated utilization of a tablet device as an mLearning tool.

DISCUSSION

Although no major change in attitudes and preferences existed between this study and the Conole et al. (2006) study; that is in itself an interesting finding. With the ever-changing advances in technologies in the intervening years between studies (e.g., Google Glass, iPad, and ubiquitous touch screens) the laptop is still the workhorse of mLearning and the preferred student technology.

The preference for the discussion board among the students surveyed in this research is surprising. This shows a striking gain in popularity compared to the Conole et al. (2006) study; friends/family communications notwithstanding. Given these findings, certain questions can be hypothesized. Has the Discussion Board technology matured to a point of acceptance and usability over the years? Or have educators and students become more adept at using the technology? Are their cultural factors in Discussion Board preferences between the U.S. and U.K. students? Each of these questions provide opportunities for further research (see below).

Research Questions

With regard to research question one, "Are students utilizing smart phones and other technologies for their courses?": the answer is yes. Students indicated that they are using smartphones and other technologies for their courses. Regarding research question two, "If yes: to what degree and how?" and research question three, "What technologies appear the most useful or preferred?": 60 percent of students indicated that they utilized smart phones as an mLearning tool. Laptop usage exceeded smartphone usage by 30 percent. Tablet devices were the third most utilized at 45 percent. In terms of research question four, "How are these technologies being utilized,": students favor the laptop for student-to-student communication. In terms of personal use, preference for mobile phones was indicated. With regard to student-to- student communication tool utilization, email was the most utilized at 85 percent, followed by texting at 65 percent. For student-to-teacher/tutor communication, 88 percent favored email with no other significant communication methodology preference reported.

LIMITATIONS

As the sample was specifically limited to one university, the potential to generalize the results could be similarly limited. As with any online survey instrument, there are issues such as self-selection bias (Wright, 2005).

While the Conole et al. (2006) study encompassed a larger geographical area (the U.K.'s Higher Education Academy), the sample was limited to a much smaller geographically bounded area. In this case: east-central Indiana. This limitation presents an opportunity to expand this study to other academic institutions in the United States (see the following text).

OPPORTUNITIES FOR FUTURE RESEARCH

Pedagogical practices with mLearning technologies should evolve over time. As such, a suggested future research endeavor would be a longitudinal study that samples the cross-sectional group (a mid-sized Indiana research and teaching university) at several intervals over time. This would reveal any changes or trends within the sample group as related to mLearning adoption and practice.

For both longitudinal and larger regional sample reasons, replication of this study at other universities is also suggested. This will give a broader picture (over time) of student experiences with mLearning technology. Of particular interest would be university students in less developed countries. This will provide a comparison of technology adoption across a wider socio-economic stratification.

Given the advances in technology in the years that have elapsed since the Conole et al. (2006) study, there assuredly will be further advances in technologies. In a number of categories, there was a large preference for an "other" category within the mLearning communication tools section. With some qualitative research, the identity of this category could be found.

Discussion Board preferences by students in the United States as opposed to those in the United Kingdom (see discussion above) is another opportunity for further research. These preferences could be a result of cultural differences or of technology maturation. Advancements in technology within the years between studies could account for the difference. Conversely, this could be a result of familiarity and utilization of this technology. The Discussion Board has been a staple technology in learning and in online education for quite some time (Blackmon, 2012).

CONCLUSION

In this research, findings that resulted from a study of US students' use and experiences with mobile technologies were presented. The survey population was derived from one mid-sized Indiana teaching and research institution. The students typically employed several types of mLearning technologies such as laptops, smart phones, and tablets. The findings suggest that laptops are the preferred mLearning technology and are utilized in a number of categories such as student-to-student communications as well as for completing learning assignments. These findings are congruent with the Conole et al. (2006) research findings. Of notable difference was the U.S. students' preference for Discussion Boards as an online learning facility compared to the British students surveyed in prior years.

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Value of Informal Learning Environments for Students Engaged in Engineering Design

By Cameron Denson, Matthew Lammi, Tracy Foote White, and Laura Bottomley

ABSTRACT

A focus group study was conducted with purposefully sampled student participants solving an engineering design challenge during a one-week engineering summer camp held at a research-intensive university in the southeast. The goal of the study was to further understand the student experience and ascertain the perceived value of an informal learning environment for students engaged in an engineering design challenge. Emergent themes are provided to illustrate the primary challenges related to the engineering design challenge and the aspects of the engineering summer camp that were beneficial to the student participants. It is anticipated that the results of this study will constructively add to the literature on learning and teaching in engineering design across informal and formal learning environments.

Keywords: informal learning environments, engineering design, focus group studies

INTRODUCTION

Education in the Science, Technology, Engineering, and Mathematics (STEM) fields has many economic and national security implications, making the issue of STEM education reform and access one of national concern (Kuenzi, 2008). At the forefront of this reformation is the need to attract a larger and more diverse student population to STEM fields (Chubin, 2005). The challenge of meeting the nation's demands for increased diversity is exacerbated by the inability of formal learning environments to introduce underrepresented students to STEM professions (Denson, 2012). This highlights the importance of informal learning environments and Martin (2004) suggests informal settings will be instrumental in the reformation of STEM education. Currently, there is a dearth of literature articulating the ways in which these informal learning environments are having an impact on students in the STEM fields.

This paper reports on a focus group interview conducted with students from an engineering summer camp held at a research-intensive institution in the southeast. The focus group interview helped identify the value of an engineering summer camp for students interested in STEM fields. In an effort to identify aspects of the informal learning environment that were particularly beneficial for students, the researchers felt it appropriate to utilize qualitative research methodology to satisfy the goals of the study.

INFORMAL LEARNING ENVIRONMENTS

It is estimated that during the school years of students, 85% of these learners' time will be spent outside of a classroom (Gerber, 2001). This illustrates the importance of providing opportunities for learning that are outside of the traditional learning environment. Informal learning environments provide these opportunities and have been an integral part of education for years (Martin, 2004). The continued study of informal learning environments may provide insight into ways the nation can begin to attract a STEM workforce that is more diverse. The merits of informal learning environments are known, yet the research is not clear on how such experiences benefit students (Gerber, 2001). Beyond anecdotal reporting on informal learning environments, little has been reported that documents the capacity of informal learning environments to influence learning and student development. The researchers' efforts are part of a broader study, which investigated and measured the impact of informal learning environments.

SETTING

Informal learning environments can be categorized into three major settings: (a) everyday experiences, (b) designed settings, and (c) programmed settings (Kotys-Schwartz, 2011). The informal learning environment framing this study was a one-week summer engineering camp held at a research-intensive university in the southeast and is categorized as a programmed setting. Programmed settings are characterized by structured programs that take place at a school and/or community-based organization and science organizations (Kotys-Schwartz, 2011). Founded in

1999 as an extension of the Women in Engineering Program, the engineering summer camp featured in this study offers a week-long engineering camp each summer for 9th-10th grade male and female students interested in experiencing science, technology, engineering, and mathematics.

PARTICIPANTS

Participants for this study attended a multidisciplinary session for rising 9th and 10th grade students. Student campers must pay to participate in the engineering summer camps, with financial aid provided to those in need. Approximately 90 students were placed in design teams of three students, providing the study with 30 student groups. Participants were not provided remuneration for their participation in this focus group interview study.

Participants were selected for this study using a strategy of purposeful sampling. Purposeful sampling is an effective strategy of sampling that allows for the collection of "information rich" data (Glesne, 2006). The participating teachers recommended participants for the focus group interview based on the students' performance, attendance, and overall engagement in the engineering design challenge. A total of eight students participated in the focus group interview with equal representation between males and females. The Engineering Summer Camp does place an emphasis on underrepresented student populations however their camp is available to *all* students. The focus group sample provided a mix of demographics that was reflective of the camp's broader population. For the purposes of this study, members of the focus group are entitled "participants" in this paper.

INSTRUCTORS/ADVISORS

Three high school teachers with backgrounds in science and/or math were selected as instructors for the engineering summer camp. Instructors were responsible for 30 students each equaling 10 student groups. The instructors provided guidance and instruction for the student teams while facilitating the engineering design experience. Undergraduate students as well as high school students who supported the engineering summer camp assisted instructors. It is important to note that the student participants were engaged in an engineering design challenge as part of their experience. The engineering design challenge was a central theme for the summer camp and helped frame this particular informal learning environment and the experience of the student participants.

ENGINEERING DESIGN CHALLENGE

The summer camp challenge was to design, build, and test a working model of a green roof on campus. The students were allowed one full week to complete the design challenge. The campers were given many scaffolding activities to promote engineering design habits and to practice, which included the following: problem-formulation activities (identification and scoping), developing and engaging in the investigation of green roof substrates, and were given guided field trips of local green roofs. The campers had access to a "materials resource room," which included soil, hydraulic pumps, model building materials, supplies, and tools. Participants were also allowed to submit a request for additional materials that could be purchased mid way through the week.

PURPOSE OF THE STUDY

The purpose of this study was to determine the factors of the engineering summer camp that were particularly beneficial to students. As a secondary goal, the researchers sought to investigate the biggest challenges students faced in realizing the engineering design challenge-which framed the informal learning environment. To accomplish this goal, a focus group interview was conducted with eight summer-camp participants who purposefully were selected for the study (Dey, 2004). Participants were asked two open-ended questions:

1. What were some of the hardest challenges you had to overcome in completing the engineering design challenge?
2. What do you feel you are gaining by participating in the engineering summer camp?

METHODS AND METHODOLOGY

The research team used a focus group protocol to guide the interview session. Focus groups are used to gather opinions. Focus group are unique because the interactions among participants enhances the quality of the data through a checks and balances process (Patton, 2002). These consisted of a series of interviews, conducted with five to ten participants, wherein the researcher attempts to gain a certain perspective from a particular group (Krueger, 2009). Members of the group conducted member checking, expounding on participant responses, and adding clarity to group responses. Focus groups typically have four characteristics: they include people who (a) possess certain characteristics, (b) provide qualitative data (c) are in a focused discussion, and (d) help understand the topic of interest (Krueger, 2009). In order to ascertain a perspective that was reflective of the engineering summer camp it was important to establish a "consensus" among group members. Regarding this study, researchers believed that focus group interviews were appropriate.

A semi-structured interview technique was employed to unpack the variables of the summer camp that were particularly challenging and distinguish those from which the students benefitted. This technique allowed the interviewer to digress in order to capture richer descriptions of activities before returning to the interview protocol in an effort to maintain the integrity of the interview process (Krueger, 2009).

The facilitator posed the two open-ended questions. After the first question was posed (What were some of the hardest challenges faced in completing the engineering design challenge?), the facilitator asked additional questions stemming from received answers for the purpose of clarification and confirmation. This allowed the participants to answer a multitude of questions with minimal probing from the facilitator. After a number of supplementary questions had been pulled from the first question, the second main question was then posed as a concluding question (What do you feel you are gaining by participating in engineering summer camp?). Again the process was repeated and the facilitator listened carefully to answers and pulled additional information through follow-up questions. Notes were taken to ensure that data could be crosschecked with the audio recording.

Interviews were recorded digitally and transcribed at a later date by a professional transcriptionist. The interviews were conducted using two researchers; one who led the interviews while the other researcher took field notes. The interview lasted approximately 40 minutes.

THEORETICAL FRAMEWORK

To build towards theory of impact and influence relative to the camp's activities and student participants, the researchers looked for emergent themes that were present. Focus group interviews are well suited for qualitative investigation including those that employ emergent theme analysis (Webb, 2001). An emergent theme analysis approach was used to arrive at an understanding of the value of an informal learning environment for students engaged in an engineering design activity (Ayres, 2003). This strategy is useful when striving to render a conceptual understanding from the data (Charmaz, 2003). This approach yields themes that are formed from the grouping of codes according to conceptual categories that reflect commonalities among coded data (Glaser, 1967).

In this study, the researchers searched for emergent themes formed from the focus group participants' responses. This was accomplished by looking at the transcribed recordings and notes that were taken during each interview session. Initial data examination and coding were conducted independently by one researcher, and this process was repeated using the services of another qualitative researcher prior to coming together to discuss the themes that were prevalent. After individual analysis, the researchers came together to identify themes and correlate results in order to establish inter-rater reliability. The researchers met with a third party to discuss emergent themes and to establish consensus among the findings. The emergent themes presented in this study are the result of themes identified by both coders and agreed upon by the third researcher. Individual researchers reviewed collected responses and gradually went from coding to categories, and eventually theory building; leading to the development of emergent themes (Harry, 2005).

FINDINGS

The guiding question for this study is as follows: What is the value of an engineering summer camp for students engaged in an engineering design activity? In order to understand students' value of the engineering summer camp, focus group interviews were conducted with purposefully selected student participants. The following themes formed from the focus group interview fell into the two distinct categories, *biggest challenges faced*, which included (a) dealing with constraints, (b) lack of time, and *benefits of the summer camp* which included, (c) use of mathematical modeling (d) field experience, and (e) teamwork.

BIGGEST CHALLENGES FACED

Dealing with Constraints

When speaking of the **biggest challenge** that the students faced in engaging in an engineering design challenge, these students agreed that *dealing with constraints* was one of their toughest challenges. One student lamented,

> *"I think that the, the weight restraint is kind of difficult because… Even all of the area can be affected by your weight limit constraint."*

The student's peers agreed with the statement adding,

> *"Yeah I agree with her 'cause like finding out which layers to put while still staying within the weight limit and figure out what drain and what didn't. But I think that a lot of it is how you use your budget instead of you know just having a number. You have to work around it just like we did."*

Time Allocation

When given the opportunity to speak about other challenges faced in the engineering design challenge participants felt that *lack of time* overall was a big challenge to overcome. One student argued,

> *"I think some of the steps required more days and even though we managed to do it, it was kind of rushed at the end…"*

Another student added,

> *"We didn't have much time on the project so I just suggest we have like some more time to do it."*

Asked if the camp was extended by a week, the group unanimously agreed that

> *"... yeah I think if this camp were longer and I did have the opportunity to stay again, I would definitely do it."*

BENEFITS OF SUMMER CAMP

When speaking to the camp participants the following themes presented themselves among the student participants regarding the **benefits of the summer camp** to include the use of mathematical modeling (application of math and science), a field experience, and teamwork.

Using Mathematical Modeling (Application of Math and Science)

Speaking about the skills that they were able to develop in the camp, the participants felt that the *use of mathematical modeling* and practical application of math and science was key

> *"… then I come to this camp and they're like make a mathematical model so you can figure out how big this thing is."*

Another participant concurred adding,

> *"… and use math for like in the real world you're more interested it's very important not saying it's boring your selling cookies so I'm not gonna care about this."*

Field Experience

Another **benefit of the summer camp** as provided by the student participants included *field experiences*. When asked about improvements for the summer camp a student suggested,

> *"… I wish we could take like more field trips I guess."*

When asked to describe the best part of the summer camp another student offered,

> *"My favorite part of this camp was the Hunt Library. It was really cool and I really liked it."*

When asked to discuss the overall experience a student participant simply offered,

> *"… I love the field trips."*

Teamwork

Overwhelming the most emergent theme that student participants presented regarding the benefits of this summer camp included the value of *teamwork*. The opportunity to work with like-minded students was a big benefit of the camp as one student attested,

> *"I think being in contact with other kids who have kind of like the same mind set as me. That's pretty cool too."*

Working with like-minded students also produced a sense of trust for the student participants as provided in this statement,

> *"... it also makes me kind of trust people a lot more cause when you're working in groups everybody here is real smart so they can always do their part…"*.

And finally the advent of teamwork led to trust building among the participants,

> *"And like you actually have other people that you can rely on to do their part and pull their own weight."*

SUMMARY

This study explored the value of a summer engineering camp for all students, including those who are underrepresented. The engineering camp was framed by the introduction of an engineering design challenge that students completed and presented at the end of the camp. Using emergent theme analysis, emergent themes were established, which allowed us to establish the benefits of the summer camp as well as the biggest challenges faced when students engaged in the engineering design challenge. Researchers found that the **biggest challenges faced** were (a) dealing with constraints and (b) lack of time, while the **benefits of the summer camp** included the use of mathematical modeling (application of mathematics and science), a field experience, and teamwork.

The findings from this study present the specific factors of an informal learning environment that held value for students engaged in an engineering design activity and their development as students. Findings from this study support Martin's (2004) notion that informal learning environments provide opportunities for school-age children to learn outside of traditional learning settings. Further, it aids in providing clarity on the ways in which informal learning environments benefit students (Gerber, 2001). The researchers' discovery of the *biggest challenges faced* and the *benefits of a summer engineering design camp* for students offers factors to consider when designing and implementing informal learning environments. Knowing such information is of importance, as informal settings are believed to hold a valuable role in reforming STEM education (Martin, 2004).

Results from this study also report on the types of activities that are particularly attractive for populations of diverse students. The need to attract a diverse student population (Chubin, 2005) has hastened the call for informal learning environments, an integral role in the reformation of STEM education at the secondary level. The results of this study strengthen the view that informal learning environments are integral to education while providing a milieu conducive to inquiry-based learning (Martin, 2004). The research results also give credence to the argument that engineering design provides a framework that supports the practical application of mathematics (Denson, 2014).

IMPLICATIONS

Findings from the focus group interviews have implications for the engineering summer camp, which serves as the context for the study and other informal learning environments. Results from this study will help inform camp organizers as to the types of learning experiences that are particularly beneficial to their students. Potential implications include highlighting the benefits of introducing engineering design activities in formal learning environments and the potential challenges instructors may face when attempting to facilitate such a learning experience. Possible future work would include looking at whether the impressions vary by gender or ethnicity and whether there are equivalent experiences.

This study also revealed many pertinent questions that should merit the need for future studies, including: Are there aspects of the camp that are perceived as more important/valuable by women compared to men or by someone from an underrepresented ethnic group? Other findings include implications for formal learning environments. Many students mentioned a benefit of learning the value of mathematical modeling. This may offer insight into ways instructors can incorporate more engineering into the formal curriculum as a way to improve math skills of students. Other questions that future studies should ascertain include: Do students' perceptions of the challenges change over the course of their engineering experience? For students who have had an engineering camp experience, are they seen differently among campers without experience? Are the skills developed in the engineering summer camp transferable to formal learning environments? In what ways are the soft skills developed, that is, is a skill such as teamwork, transferable to other academic and work environments?

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The "Who, What, and How Conversation": Characteristics and Responsibilities of Current In-service Technology and Engineering Educators

By Jeremy V. Ernst and Thomas O. Williams

ABSTRACT

This study, using the Schools and Staffing Survey (SASS), investigates K-12 technology and engineering educator and service load similarities and differences as they compare to the broader educational population. Specifically, teacher demographics, educational levels, certification status/pathways, and student caseload characteristics are explored. Results indicate that technology and engineering educators have a notable background and preparation distinctions to that of peer educators. Additionally, there are notable distinctions in the student population in which this group of educators serve.

Keywords: Schools and Staffing Survey, teacher characteristics, teacher caseload

INTRODUCTION AND BACKGROUND

The technology and engineering education in K-12 settings has drawn increasing attention from teacher educators, researchers, and historians regarding its classroom context, curricula, pedagogies, and paradigm shift. A considerable amount of research grounded in this area has been conducted discussing the historical foundations, current trends, needs, and issues. This research addressed K-12 technology and engineering education in various aspects of programs and practice (Dugger, 2007; Dugger, French, Peckham, & Starkweather, 1992; Meade & Dugger, 2004; Sanders, 2001), preparation, licensure, and endorsement (Moye, 2009; Volk, 1993; Volk, 1997; Zuga, 1991), and educator dynamics (Haynie, 2003; McCarthy & Berger, 2008; Zuga 1996). However, these pioneer efforts have left some inconsistencies and discrepancies. A more around representative description should be presented to reflect the overall state of K-12 technology and engineering education in the United States.

Several studies (Dugger, 2007; Newberry, 2001; Meade & Dugger, 2004; Moye, 2009; Ndahi & Ritz, 2003) have revealed vastly different conclusions regarding the landscape of technology and engineering education. For example, K-12 in-service educator count ranges from 25,258 teachers in 50 states (Dugger, 2007) to 38,537 teachers in 48 states (Newberry, 2001). Moye, Dugger, & Starkweather (2012) attributed such a variation to a number of factors: the lack of respondents to surveys, the different infrastructures of school systems, the lack of leadership of technology and engineering educators, and the lack of accurate data collection from the state.

A standardized reporting set could potentially provide a prevailing reporting format. The U.S. Department of Education and the National Center for Education Statistics (NCES) employ standardized reporting mechanisms under federal educational funding clusters and guidelines, resulting in a comprehensive account of educators and their characteristics with each educational discipline. Data collected within this system spans the nation and results in an inclusive collection of metrics from educators within a range of educational disciplines. One instrument within this reporting complex is the Schools and Staffing Survey (SASS).

Research Questions

Considering the variation and inconsistencies in reporting within technology and engineering education, this research was launched to assist in building a national profile of these discipline-based descriptors. Additionally, the research questions assisted in determining similarities and differences between technology and engineering education and the broader educational community. Specifically this research addressed the following:

1. What are the characteristics and credentials of technology and engineering educators and how do they compare to other in-service educators?

2. What student population features and characteristics are identifiable within technology and engineering classrooms, and how do they compare to other in-service educators?

Schools and Staffing Survey

SASS has been described by the Institute of Education Sciences as:

> "… [a] large-scale sample survey of K-12 school districts, schools, teachers, library media centers, and administrators in the United States. It includes data from public, public charter, private, and Bureau of Indian Education (BIE) funded school sectors. Therefore, SASS provides a multitude of opportunities for analysis and reporting on elementary and secondary educational settings. The Schools and Staffing Survey provides data on the characteristics and qualifications of teachers and principals, teacher hiring practices, professional development, class size, and other conditions in schools across the nation (Tourkin, Thomas, Swaim, Cox, Parmer, Jackson, Cole, & Zhang, 2010, p. 1)."

Data utilized within this study comes from five questionnaires within the 2011-12 SASS: a School District Questionnaire, Principal Questionnaire, School Questionnaire, Teacher Questionnaire, and a School Library Media Center Questionnaire. The SASS Teacher Questionnaire (SASS TQ) targeted questions to gather data from teachers that would identify their levels of education and training, teaching assignments, certification, and workload.

METHODOLOGY

The methodology closely followed that of Ernst and Williams (2014) and Ernst, Li, and Williams (2014). This study consisted of a secondary analysis of the SASS-TQ dataset administered by the NCES. Initial access was applied for and authorized by the NCES to Virginia Tech. The access provided a member of the research team with designated single-site user admittance. Specific protocol and reporting information was submitted and subsequently accepted, where the NCES and Institute for Educational Sciences (IES) authorized approval and release. The NCES and IES require that weighted all n's be rounded to the nearest ten to assure participant anonymity. Therefore data in tables and narrative may not add to the total N reported because of rounding requirements.

PARTICIPANT SELECTION

In this study, the participants who gave subject-matter codes relating to technology and engineering education for Question 16 in the **2011–2012 SASS TQ**, "This school year, what is your MAIN teaching assignment field at THIS school?" were identified and placed in their respective disciplines. Table 1 shows associated codes and descriptors used to group technology and engineering education teachers. All demographic data presented were weighted using the Teacher Final Sampling Weight (TFNLWGT) variable, which is appropriate for descriptive statistics. T-tests employed an additional 88 replicate weights that were supplied in the SASS data file by IES. This resulted in 50,610 instances within the weighted results for all technology

TABLE 1. Technology & engineering educator SASS codes and summary descriptors representing main teaching assignment.

Area	Code	Summary Description
Technology & Engineering Education	246	Construction Technology (Construction design and engineering, CADD and drafting)
	249	Manufacturing Technology (electronics, metalwork, precision production, etc.)
	250	Communication Technology (Communication systems, electronic media, and related technologies)
	255	General Technology Education (Technological systems, industrial systems, and pre-engineering)

Note. SASS is the Schools and Staffing Survey and engineering education teachers. Data from the **2011–2012 SASS TQ** for technology and engineering educators were extracted and analyzed using a variety of descriptive statistics.

VARIABLES ANALYZED

Gender, Age, Teaching Experience, and Employment Status.

The gender of technology and engineering education teachers was determined by SASS TQ question 78, "Are you male or female?" Teachers' age was determined by the SASS TQ variable AGE_T. Teaching experience was determined by the SASS TQ variable TOTYREXP. Teaching experience is calculated as the sum of all years taught full or part-time in public and private schools. Status was determined by the SASS TQ variable FTPT. This is a two-level teaching status variable that indicates whether the respondent is teaching full-time or part-time.

Race and Ethnicity.

The racial make-up of technology and engineering education teachers was determined by two questions on the SASS TQ. Question 80 asked, "Are you of Hispanic or Latino origin?" The respondent answered either yes or no. Question 81 asked, "What is your race?" Respondents were to mark one or more of the listed races to indicate what race(s) they consider themselves. The SASS TQ provided five choices for race: White, Black/African-American, Asian, Native Hawaiian/Other Pacific Islander, or American Indian/Alaska Native. Because respondents are allowed to make more than one selection, the percentages may not always add up to 100 percent.

Level of Education.

The SASS TQ variable HIDEGR was used to determine the highest degree obtained and held by the teacher. This variable can range from Associate through Ph.D. and was used as the indicator for education level. This variable does not take into account multiple degrees (e.g., double Bachelors or double Masters), only the highest degree obtained.

Certification Status, Route, and Qualification Status.

Question 37a, "Which of the following describes the teaching certificate you currently hold that certifies you to teach in THIS state?" was used to identify whether or not the teachers were certified in the subject(s) they teach. The question was used to determine whether the certification route was alternative or through a traditional college program was Question 41, "Did you enter teaching through an alternative certification program?" An alternative program is designed to expedite the transition of non-teachers to a teaching career, for example, a state, district, or university alternative certification program. The respondent was requested to indicate either an alternative or traditional path to certification.

Question 42, "This school year, are you a Highly Qualified Teacher (HQT) according to your state's requirements?" was used to determine whether the teacher was presumed to be HQT. Generally, to be highly qualified, teachers must meet requirements related to (1) a bachelor's degree, (2) full state certification, and (3) demonstrated competency in the subject area(s) taught. The HQT requirement is a provision under the No Child Left Behind (NCLB) Act of 2001.

Caseload.

The SASS TQ variable PUPILS-D was used to determine the mean total number of students taught. Teachers were asked how many students they teach per day in their content area. To specifically address the research questions relating to students with categorical disabilities and limited English proficiency and service load, data derived from Questions 14 and 15 on the SASS TQ were analyzed. Service load was calculated by the researchers to be the sum of responses to Questions 14 and 15.

The number of categorized students who are served was determined by responses from teachers who reported teaching students with recognized disabilities requiring an individualized education plan as determined from the Question 14, "Of all the students you teach at this school, how many have an Individualized Education Program (IEP) because they have disabilities or are special education students?" Teachers either checked none or entered an integer.

Likewise, the number of students identified as LEP was determined by responses from teachers who reported teaching students who did not speak English as their primary language and who had a limited ability to read, speak, write, or understand English. This number was derived from the response to Question 15, "Of all the students you teach at this school, how many are of limited-English proficiency? (Students of limited-English proficiency [LEP] are those whose native or dominant language is other than English and who have sufficient difficulty speaking, reading, writing, or understanding the English language as to deny them the opportunity to learn successfully in an English-speaking-only classroom.)"

RESULTS

Gender, Age, Teaching Experience, And Employment Status

Demographic information concerning teacher gender, age, teaching experience, and teaching status is presented in Table 2. One notable finding was gender disparity between the two groups. With regard to gender, there is a large discrepancy between technology and engineering education teachers and all other teachers. Technology and engineering education teachers are predominantly male (75%), while the category "all other teachers" was predominately female (77%).

Test statistics for information reported as a mean (teacher age and teacher experience) were tabulated and evaluated in efforts to determine differences, if any. Even though age and experience were statistically significantly different, there appeared to be little practical difference between the groups. The profile for both groups was quite similar in age and experience and the majority were employed as full-time teachers.

TABLE 2. Technology & engineering educator gender, age, teaching experience, and status as reported on the 2011-2012 SASS.

Area	Male	Female	Mean Age	Mean Experience	Full-time Status
Technology & Engineering Education (n = 50610)	38150 (75.4)	12460 (24.6)	46.72 *p = <0.001	15.48 *p = <0.001	46730 (92.3)
All Other Teachers (n = 3334570)	763480 (22.9)	2571090 (77.1)	42.34	13.76	3104110 (93.1)

** P-value for two-sample location test of difference in mean (p = 0.05)*

Note. *SASS is the Schools and Staffing Survey.*
All n's rounded to the nearest ten per NCES and IES requirements.

Race and Ethnicity

Teachers' self-reported racial description is reported in Table 3. This information was collected through the survey and was reported for the purposes of establishing a demographical make-up of technology and engineering education teachers. Because participants were allowed to make more than one selection, the percentage may not equal 100 percent in Table 3. Both groups were very similar in racial make-up. The only exception was the category "Black/African-American" being approximately three percentage points lower for technology and engineering education teachers.

Level of Education

Table 4 shows the highest level of education that was reported. It should be noted that only the highest degree obtained is reported. Reported are outcomes of bachelors, masters, educational specialist, and doctorates earned as a single highest degree obtained. In "highest level of education obtained," technology and engineering education teachers are less likely to have a Master's degree and more likely to have a "bachelor's degree or less" than the of all other teacher groups.

TABLE 3. Technology & Engineering educator self-reported racial category from the 2011-2012 SASS.

Area	Hispanic	White	Black/ African-American	Asian	Native Hawaiian/ Other Pacific Islander	American Indian/ Alaska Native
Technology & Engineering Education	3560 (7.0)	46520 (91.9)	2410 (4.8)	1140 (2.3)	250 (0.5)	1370 (2.7)
All Other Teachers	260550 (7.8)	3000320 (90.0)	254740 (7.6)	73930 (2.2)	11110 (0.3)	47280 (1.4)

Note. SASS is the Schools and Staffing Survey. Racial categories were taken directly from the SASS survey. Percentages are in parentheses.
Percentages may not add to 100 because respondents were allowed to choose multiple categories. All n's rounded to the nearest ten per NCES and IES requirements.

TABLE 4. Technology & Engineering educator highest degree obtained.

Area	Bachelors	Masters	Educational Specialist	Doctorate
Technology & Engineering Education	27380 (54.1)	20430 (40.4)	2330 (4.6)	460 (0.9)
All Other Teachers	1450580 (43.5)	1593200 (47.8)	254490 (7.6)	36320 (1.1)

Note. Percentages are in parentheses. All n's rounded to the nearest ten per NCES and IES requirements.

Certification Status, Route, and Qualification Status

In Table 5 the certification status, certification route, and qualification status of technology and engineering educators are shown specific to standard state certification, alternative certification, traditional certification, determination of "highly qualified" and either not "highly qualified," or unknown to the respondent. The profile for technology and engineering education teachers shows that they are less likely to hold a regular or standard state teaching certificate (85.6% vs. 91.3%), more likely to receive certification through an alternative certification program (21.6% vs. 14.5%) and are less likely to be highly qualified in all subjects taught (59.3% vs. 72.9%) than the category all other teachers.

Caseload

The caseloads of technology and engineering education teachers are illustrated in Table 6 pertaining to total students served, students with an Individualized Education Program (IEP), students who are identified as limited in English proficiency, and total service load of students with IEPs and who are limited in English proficiency. Test statistics were also tabulated and evaluated in efforts to determine differences in student caseload categorizations, if any.

Technology and engineering education teachers were found to have a statistically significantly larger caseload, categorical student load, and service load than all other educators. Their caseload is almost double, with technology and engineering education teachers having a caseload of approximately 92 students and the category "all other teachers" a caseload of approximately 52 students. Technology and engineering education teachers also teach more students with disabilities and have a higher service load than the category "all other teachers." With regard to LEP students, no statistically significant differences were found.

SUMMARY

According to the NCES administered SASS TQ, technology and engineering educator content can be categorized in four areas: (1) construction technology, (2) manufacturing technology, (3) communication technology, and (4) general technology education. Based on these four collective teacher groups, there was no significant difference in the numberof LEP students for technology and engineering teachers

(M = 7.60, SD = 20.24) and all other teachers (M = 7.16, SD = 23.89); t (88) = 0.04, p = 0.98. However, there was a significant difference in the number of IEP students for technology and engineering teachers (M = 18.87, SD = 25.12) and all other teachers (M = 11.26, SD =16.77) for; t (88) = 4.63, p = < 0.001; service load for technology and engineering teachers (M = 26.47, SD = 35.30 and all other teachers

TABLE 5. Technology & Engineering educator certification, career path entry, and qualification status as reported on the 2011–2012 SASS.

Area	Regular or standard state certificate	Alternative certification program	Traditional certification program	Highly qualified in all subjects taught	Unknown or not highly qualified
Technology & Engineering Education	43410 (85.8)	10930 (21.6)	396730 (78.4)	29990 (59.3)	12860 (25.4)
All Other Teachers	3045630 (91.3)	483670 (14.5)	2850900 (85.5)	2430390 (72.9)	587900 (17.6)

Note. *SASS is the Schools and Staffing Survey. Percentages are in parentheses. All n's rounded to the nearest ten per NCES and IES requirements.*

TABLE 6. Technology & Engineering educator caseloads as reported on the 2011–2012 SASS.

Area	Mean number of students served	Mean Categorical	Mean LEP	Service Load
Technology & Engineering Education	91.76 *p = <0.001	18.87 *p = <0.001	7.60 *p = 0.98	26.47 *p = <0.001
All Other Teachers	51.83	11.28	7.16	18.44

** P-value for two-sample location test of difference in mean (p = 0.05)*

Note. SASS is the Schools and Staffing Survey. Categorical are students with disabilities with individualized education programs. LEP is limited English proficiency. Service Load is the sum of Categorical and LEP.

(M = 18.44, SD=32.05) for; t (88) = 3.68, p = < 0.001; teacher's age for technology and engineering teachers (M = 46.72, SD = 11.05) and all other teachers (M = 42.34, SD = 11.44) for; t (88) = 7.09, p = < 0.001; number of students served for technology and engineering teachers (M = 91.76, SD = 71.39) and all other teachers (M = 51.83, SD = 76.43 for; t (88) = 8.73, p = < 0.001; average class size for technology and engineering teachers (M = 18.87, SD = 25.13) and all other teachers (M = 11.28, SD =16.77) for; t (88) = 8.85, p = < 0.001; total years teaching experience for technology and engineering teachers (M =15.46, SD = 10.19) and all other teachers (M = 13.76, SD = 9.38) for; t (88) = 3.32, p = < 0.001.

Evidenced through findings of this study, technology and engineering educators have notable background and preparation distinctions to that of peer educators. Additionally, there are notable distinctions in the student population in which this group of educators serve. Uniqueness in this case presents an opportunity to fill a current void in serving a vital student preparatory role, enriched through educational as well as life experiences of the teacher. According to the Bureau of Labor Statistics, there is an emerging growth in STEM occupations on the horizon (Richards & Terkanian, 2013). As our economy becomes increasingly dependent on STEM fields, rational decisions about scientific and engineering issues drive the need for society as a whole to become more STEM literate (Ravitch, 2013). Technology and engineering education provides equal access to quality STEM academic programs, especially for underrepresented student populations (Spring, 2011). This equal access is necessary for the increase in diversity in the classroom (Ernst, Li, & Williams, 2014).

One proactive solution includes advocacy of inclusive STEM education environments, promoted through formalized teacher learning opportunities. When teachers provide inclusive STEM-focused experiences in an integrated fashion, a positive learning culture is created where students realize importance and value in education (Behrend, et al., 2014; Kearney-Rich, 2014). This strategy not only increases underrepresented student participation in high quality STEM learning but also purposefully links local economies, communities, and universities in conception and delivery (Lynch, Behrend, & Peters, 2013; Lynch & Zipkes, 2012). This is an approach from which students, teachers, communities, as well as technology and engineering education teachers can all benefit. However, in order for these potentials to become a realization, determination of technology and engineering educator preparedness must be considered.

Note: This paper was presented at the 101st Mississippi Valley Technology Teacher Education Conference in St. Louis, MO.

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Examining the Demographics and Preparation Experiences of Foundations of Technology Teachers

By Tyler S. Love

ABSTRACT

When the Standards for Technological Literacy were released in 2000, Technology and Engineering (T&E) educators were expected to integrate concepts from other content areas within the context of engineering design and problem solving (ITEA/ITEEA, 2000/2002/2007). Fourteen years later, the Next Generation Science Standards called for science educators to teach engineering content and practices within their curricula (NGSS Lead States, 2014). These integrative standards have increased the demands placed on pre- and in-service teacher preparation efforts to ensure science and T&E educators are properly prepared to teach cross-disciplinary concepts. However, requisite for suggesting changes to adequately prepare educators for teaching such concepts, the demographics and preparation experiences of those teaching within these content areas must be thoroughly examined. This is especially important in T&E education, where there are fewer highly qualified T&E educators than openings in the United States (Moye, 2009). Given this shortage it begs to question, "What are the demographic and preparation experiences of those tasked with teaching T&E courses?"

This study examined the demographic and background characteristics of 55 individuals who were teaching Foundations of Technology (FoT), the International Technology and Engineering Educators Association's (ITEEA) flagship course. Furthermore, this research investigated the types and amount of formal and informal preparation experiences that participating FoT teachers completed within science and T&E education. The findings revealed substantial variations among the preparation experiences of those participants in this study. From these findings, recommendations to better prepare FoT teachers for integrating science concepts were suggested.

Keywords: technology and engineering education, STEM education, teacher demographics survey, teacher preparation, pedagogical content knowledge

INTRODUCTION

Today's Technology and Engineering (T&E) educators are expected to explicitly teach naturally intersecting STEM concepts to help students solve authentic design problems. This is not a new idea however, given that fifteen years ago the Standards for Technological Literacy (STLs) charged T&E educators to, "reinforce and compliment what students learn in other classes" as "a way to apply and integrate knowledge from many other subject areas" (ITEA/ITEEA, 2000/2002/2007, p. 6). More recently the Next Generation Science Standards (NGSS Lead States, 2014) called for the teaching of crosscutting concepts between science and engineering, expecting science educators to also capitalize on teaching integrative concepts. Although these standards aim to develop a more STEM-literate citizenry, they have consequently changed the landscape of T&E education and what is expected of T&E educators. This change inherently places new demands on the pedagogical and content knowledge (Shulman, 1987) preparation needed to adequately teach embedded STEM concepts. With this increased focus on teaching STEM concepts in an integrative fashion, it begs to question, "What are the preparation experiences of those expected to teach these crosscutting concepts, specifically within T&E education classrooms?"

LITERATURE REVIEW

Numerous studies (Moye, 2009; Moye, Jones, & Dugger, 2015; Soboloski, 2003; Volk, 1993) have shown a steady decline in T&E education graduates over the past 45 years. Despite an increasing demand for T&E educators, the supply of these teachers in the United States dropped from 37,968 in 1995 to 28,310 in 2009 (Moye, 2009). In addition, the number of T&E education teacher preparation programs in the U.S. has dwindled from 72 in 2007 (Warner, Erli, Johnson, & Greiner, 2007) to 43 in 2015 (ITEEA, 2015b). This decrease creates a challenge for school systems seeking highly qualified T&E educators to fill vacancies, which is important in certain states with a T&E education graduation requirement. Seven states currently require students to complete a T&E education course in order to graduate high school (Moye, Jones, & Dugger, 2015). As a result, schools have been left to fill these vacancies with teachers from other content areas (e.g., business education, art education). This problem, along with the call for teaching integrative concepts (ITEA/ITEEA, 2000/2002/2007; NGSS Lead States, 2014), has caused a drastic shift in the landscape of those now tasked with teaching T&E education courses such as FoT. Consequently, the pre- and in-service preparation experiences needed to prepare T&E teachers to adequately integrate STEM concepts has also shifted.

Recent research by Litowitz (2013, 2014) and Strimel (2013) studied various experiences contributing to the preparation of T&E educators. Within these studies they examined the college coursework of T&E educators, including science courses. Litowitz (2013, 2014) conducted an analysis of course requirements by U.S. T&E teacher preparation programs. From this study he found that on average, 42% of T&E teacher education programs only required the completion of Physics I, whereas 33% required students to take either a physics, a biology, or a chemistry course. Only one program (4%) required an advanced level science course, which was Physics II (Figure 1). Based on his analysis of requirements in existing programs, Litowitz (2013, 2014) recommended that the only science course T&E teacher preparation programs should require students to complete is physics.

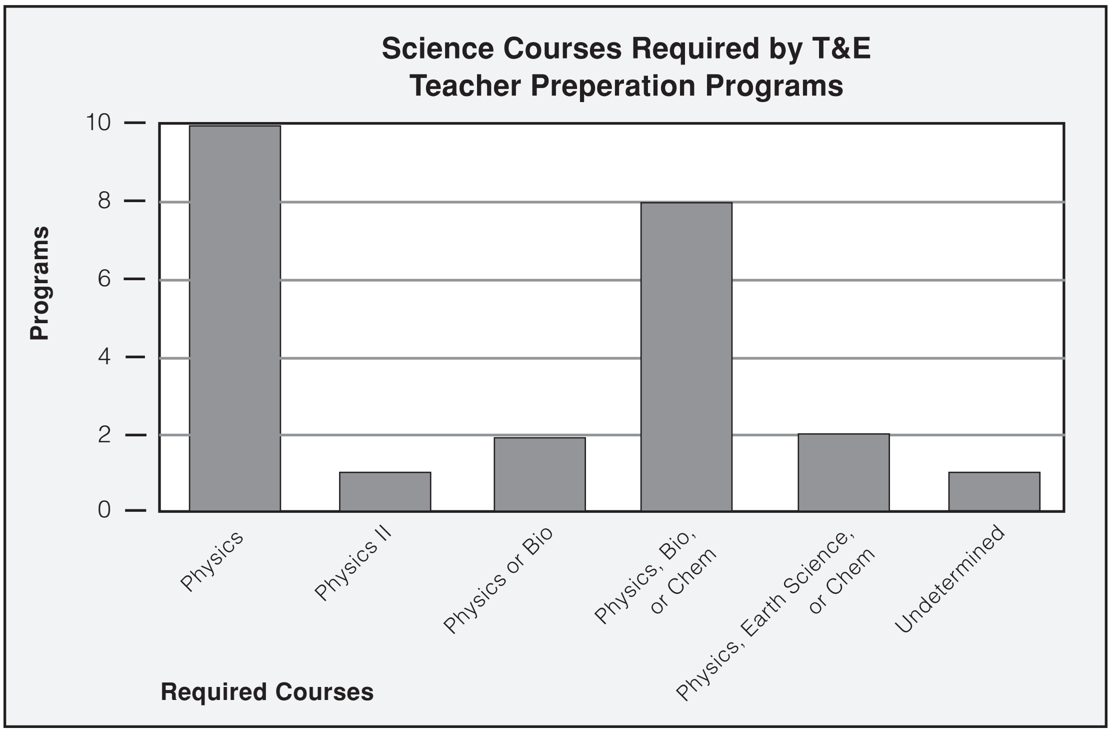

Figure 1. Created from "A Curricular Analysis of Undergraduate Technology & Engineering Teacher Preparation Programs in the United States" by L. S. Litowitz, 2014, Journal of Technology Education, 25(2), p. 75. Copyright 2014 by Virginia Tech. Created with permission.

Strimel (2013) conducted a study surveying 53 teachers who participated in a five-day summer FoT professional development session among four states. One of the research questions in his study examined, "How many college science courses have you completed?" He did not delineate between undergraduate and graduate courses. Of the 53 participants, he found chemistry was the most common course completed. Slightly less than half (42%) reported taking at least one chemistry course, and 19% took at least two chemistry courses. Biology was the next most frequently completed course, and physics was the least completed course (Figure 2). These studies provided good baseline data regarding the shifting preparation experiences of those teaching T&E education and led to further questions about T&E educators' preparation experiences.

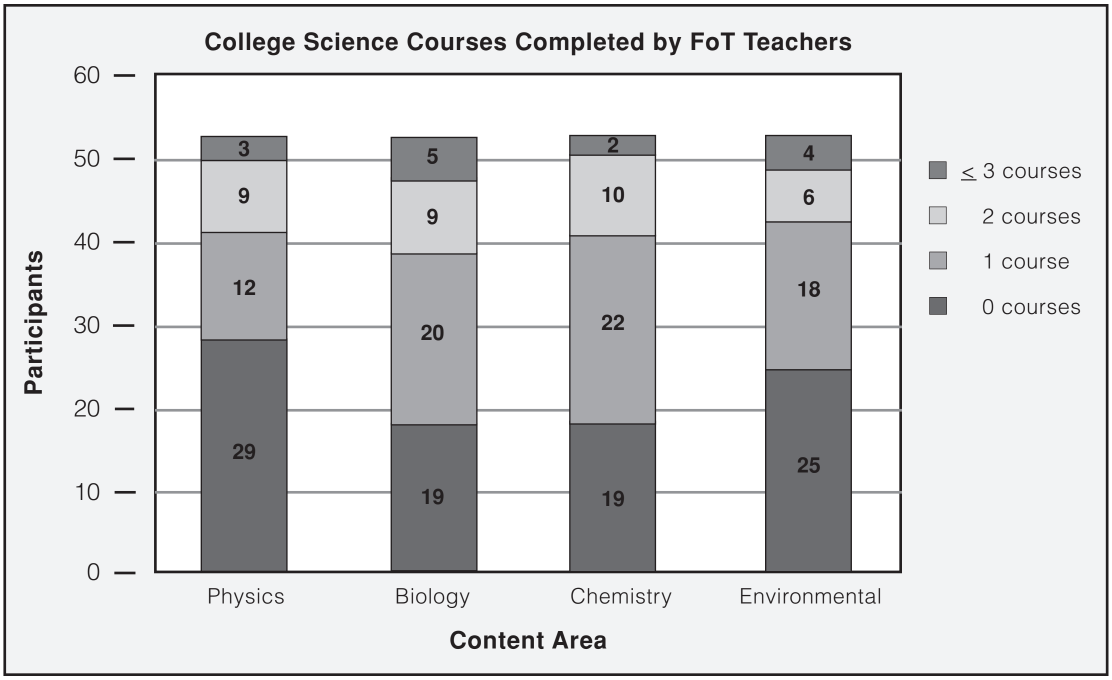

Figure 2. Adapted from "Engineering by Design™: Preparing STEM Teachers for the 21st Century" by G. Strimel, 2013, p. 451. Copyright 2013 by the Technology Environmental Science and Mathematics Education Research Centre, University of Waikato, New Zealand. Adapted with permission.

One international T&E course which is embedded with ample opportunities for making integrative STEM connections is ITEEA's flagship Engineering byDesign (EbD) course, Foundations of Technology (FoT). Many states are using FoT to help satisfy their T&E graduation requirement because it provides the framework for consistent T&E education instruction (Rhine, 2013). It is an introductory high school level learning experience that builds upon students' STEM knowledge from elementary and middle school. The FoT course aims to develop more technologically literate citizens by focusing on three dimensions: knowledge, ways of thinking, and acting and capabilities. The course was designed to engage students, allowing them to explore and increase their understanding of big ideas related to technological concepts. Specifically the course aims to give students a richer understanding of the history of technology, innovation and invention, and applying the engineering design process to solve problems directly related to the designed world (STLs 14-20). Upon completion, students should be able to synthesize major ideas from a broader systems-thinking approach by applying their understanding of core technological concepts learned throughout the course (ITEEA, 2015a). Because of these characteristics, the FoT curriculum was deemed an excellent source for examining the broad demographics and preparation experiences of those teaching it.

Despite being embedded with STEM content and practices, educators teaching T&E courses like FoT must have the adequate content and pedagogical training to properly integrate STEM concepts. Examining the pre- and in-service teacher preparation experiences of those teaching FoT is a viable starting point for informing changes to T&E educator preparation and professional development efforts, as well as enhancing curricular materials. The purpose of this study was to both investigate the demographics and select T&E and science preparation experiences of T&E educators, specifically those teaching FoT. An online survey instrument was created to address the following research questions:

1. What are the demographic and background characteristics of those teaching FoT?
2. To what extent have FoT teachers participated in select formal and informal T&E preparation experiences?
3. To what extent have FoT teachers participated in select formal and informal science preparation experiences?

STUDY METHODOLOGY

The methodology employed in this study was based upon similar research (Love, 2015), which used the same sample to analyze the correlation between preparation factors and teaching of science concepts embedded within FoT. Twenty-four county school systems in an EbD consortium state were solicited to partake in this study, 12 of which agreed to participate. All 233 FoT teachers within those 12 school systems during the fall of 2014 were invited to complete the online Technology and Engineering Educators' Science Pedagogical Content Knowledge (TEES-PCK) survey. After two weeks the survey was closed, resulting in 55 (24% response rate) complete responses, which was deemed acceptable for online surveys (Nulty, 2008). Descriptive statistics were then used to calculate the mean and percentages of the survey responses reported in the following sections of this article.

Survey Instrument

There was no single instrument readily available to collect the detailed preparation and demographic data needed for this study. Therefore, the researcher and a panel of four university faculty members with expertise in STEM education created the TEES-PCK instrument from an amalgam of surveys. The questions in this survey were derived from four instruments previously used within science (Cwik, 2012; Riggs & Enochs, 1990) and mathematics education (Ball & Hill, 2008; Perez, 2013), and were modified to fit the need of this study. The survey included questions examining teachers' self-efficacy, general demographics, informal collaborative and non-collaborative preparation experiences, and high school, undergraduate, and graduate coursework completed. A detailed description of the type of data collected within each section of the survey can be found in Table 4 of Love (2015), and the full survey instrument can be found in Appendix G of that document.

Section II of the TEES-PCK examined teachers' self-efficacy and expected outcomes regarding their teaching of T&E education. These questions were adapted from the renowned Science Teaching Efficacy Belief Instrument (STEBI) (Riggs & Enochs, 1990), and the reliability of the questions was tested using Crohnbach's alpha. This revealed high reliability (α =.883) for the self-efficacy questions and an acceptable reliability value (α = .652) for the expected outcome questions.

FINDINGS

Only a summary of the key findings from the TEES-PCK will be presented in this article because of the immense amount of data collected. The full breadth of data can be found in Appendix N of Love (2015).

Select Demographic Data

The majority of participants were Caucasian (93%) males (73%) with a mean age of 43. On average they had taught for 13 years, five of which they spent teaching FoT (Table 1).

Almost half (44%) of the participants held a master's degree; 24% possessed a bachelor's degree; and 4% had an earned doctorate.
Only 84% were certified to teach technology education. The second largest area of certification was business education, and 53% held certifications in an array of other areas (Table 2).

Table 1: *Summary of Participant Demographics and Teaching Experience*

Demographic		n (%)
Gender		
	Male	40(73)
	Female	15(27)
Ethnicity		
	Caucasian	51(93)
	African American	1(2)
	Latin American	0(0)
	Asian	1(2)
	Ugandan-American	1(2)
	African American/ Caucasian	1(2)

Table 2: *Summary of Degrees and Certifications Held by Participants*

Credential Held		n (%)
Degree		
	Bachelor's	14(26)
	Master's	24(44)
	Master's +30	10(18)
	Master's +60	5(9)
	Education Specialist	0(0)
	Doctorate	2(4)
Certification Area		
	Technology Education	46(84)
	Business Education	10(18)
	Mathematics Education	4(7)
	Other	29(53)

Among the degrees held, the majority of teachers (68%) were in technology education, with 40% earning bachelor's and 28% possessing master's degrees in this area. Other notable areas in which participants possessed bachelor's degrees were dispersed among industrial arts (11%), business education (9%), and physical and health education (8%). The second largest area in which participants held master's degrees was administration and leadership (13%), followed by curriculum and instruction (9%). The greatest number of graduate certificates held was in industrial arts (11%). Lastly, only two participants (4%) possessed doctoral degrees; one in administration and leadership, and the other in counseling (Table 3).

Table 3: *Summary of Degrees Held According to Subject Area*

Subject Area	Certificate *n (%)*	BA *n (%)*	MA *n (%)*	Doc *n (%)*
Technology Education	0(0)	22(40)	15(28)	0(0)
Administration/ Leadership	3(6)	0(0)	7(13)	1(2)
Industrial Arts	6(11)	6(11)	3(6)	0(0)
Business Education	1(2)	5(9)	0(0)	0(0)
Physical Education/ Health	0(0)	4(8)	0(0)	0(0)
Curriculum & Instruction	0(0)	2(4)	5(9)	0(0)

Note. BA = bachelor's degree; MA = master's degree; Doc = doctorate.

TEACHER PREPARATION DATA

When examining teacher preparation experiences, the majority (73%) of participants had completed a teacher preparation program and attended some form of FoT training session (51%) (Table 4). Additionally, most (73%) participants reported taking an undergraduate or graduate course that discussed methods to integrate STEM concepts within T&E education.

High School Coursework

Almost all participants (98%) had completed at least one or more high school biology course, and 85% completed one or more chemistry course. Physics was the least taken course (64%) among all high school science classes. Furthermore, a greater portion of participants completed an industrial arts class (65%) than a technology education class (44%) (Figure 3).

Table 4: *Summary of Teacher Preperation and FoT Training Experiences*

Preperation or Training		n (%)
Teacher Preperation		
	No formal training	3(6)
	Previous career	9(17)
	Teacher prep program	40(73)
FoT Training		
	None	14(26)
	One week	18(33)
	< One week	10(18)
	Integrating STEM course	40(73)

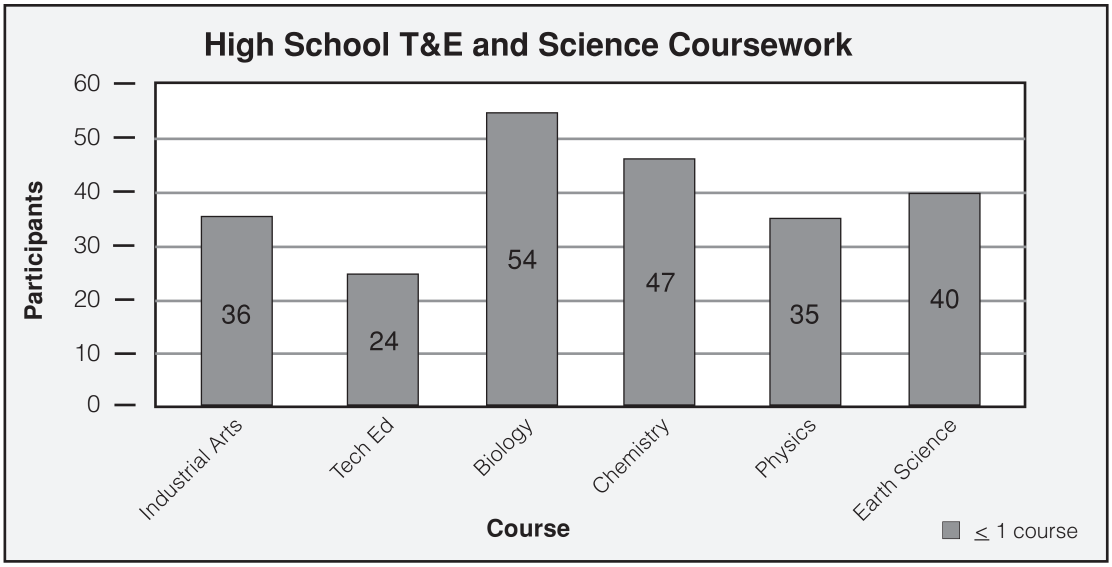

Figure 3. Summary of high school T&E and science coursework completed.

Undergraduate Coursework
When examining the science coursework completed during their undergraduate preparation, biology (27%) and physics (27%) were the most frequent courses, of which participants completed 2 or more (Figure 4).

Further analysis of participants' undergraduate coursework revealed that many completed at least one course in electronics (53%), power, energy, and transportation (PET) (49%), or technology education methods (53%). Very few completed a course in biotechnology (18%) or science methods (15%) (Figure 5).

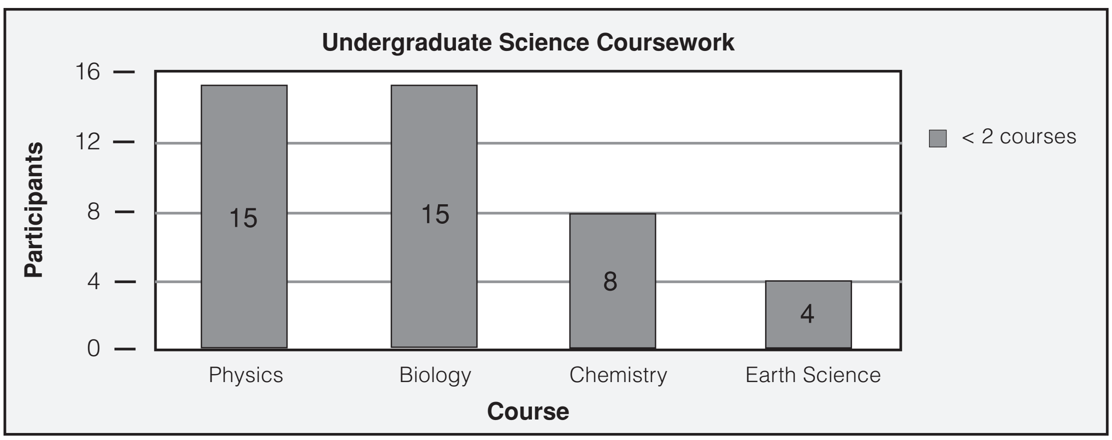

Figure 4. Summary of undergraduate science coursework completed.

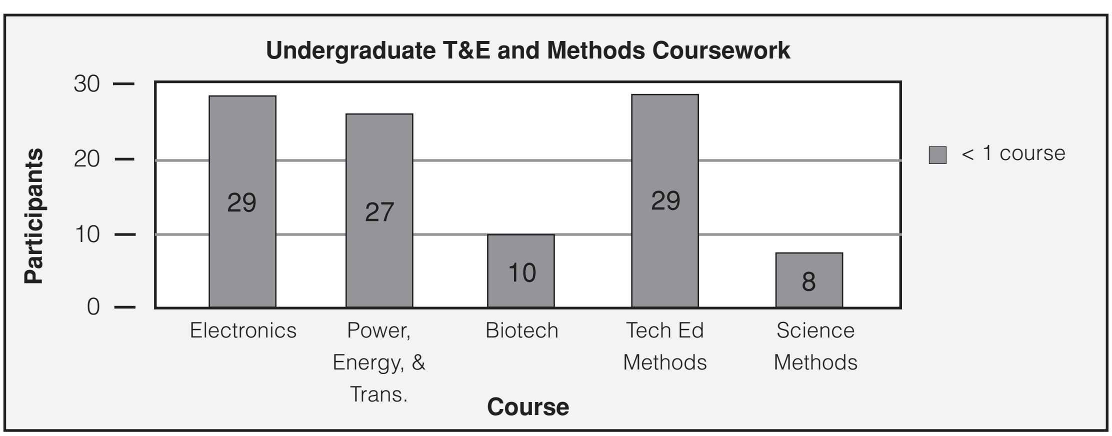

Figure 5. Summary of undergraduate T&E and teaching methods coursework completed.

Graduate Coursework

Regarding graduate coursework, almost half of the students (45%) took a technology education methods course. Other courses that were frequently taken by participants included biotechnology (18%), electronics (15%), and PET (15%). Less than seven percent completed a graduate course about science content (physics, biology, chemistry, space science) or science teaching methods (Figure 6).

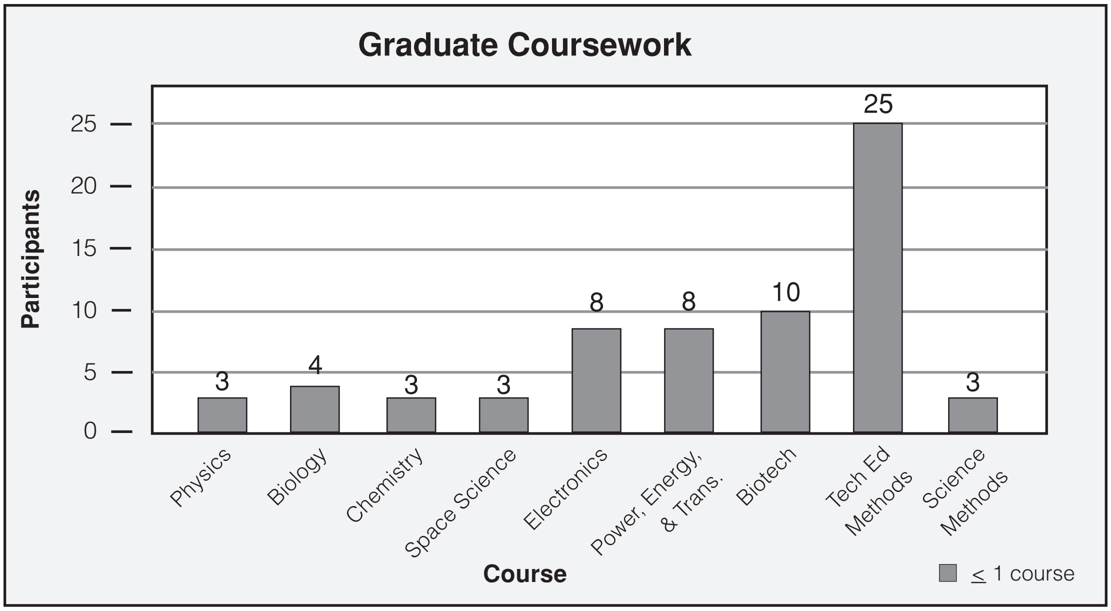

Figure 6. Summary of graduate T&E and science coursework completed.

Informal Experiences

In addition to formal coursework, it was important to examine informal collaborative and non-collaborative experiences that FoT teachers' participated in during the past three years that could have also contributed to their preparation. Most participants (58%) did not engage in any clubs or after-school activities, but among those that did, the most common club that teachers helped with was robotics (25%). These teachers spent more hours reading literature in T&E education (40%) versus science education (22%), and most reported recently participating in a T&E (75%) or science education (65%) workshop/in-service session (Table 5).

Table 5: *Summary of Participants' Informal Non-Collaborative Preparation Experiences*

Experience		n (%)
Informal Non-Collaborative		
	None	32(58)
	Robotics	14(25)
	TSA	7(13)
Literature Read		
	≤ 35 hours in T&E	22(40)
	≥ 6 hours in Science	12(22)
Workshops		
	Science	36(65)
	T&E	41(75)

Note. TSA = Technology Student Association

Teachers spent much more time participating in informal collaborative T&E experiences than science experiences. Observing T&E (69%) or science (16%) classes, and consulting with T&E (67%) or science (33%) specialists were the most frequent collaborative experiences in which teachers participated (Figure 7).

Further analysis of collaborative experiences revealed that most teachers had participated in collaborative T&E educator networks (73%), T&E education committees or task forces (45%), or collaborative science educator networks (38%). Fewer teachers (18%) reported participating in science education committees or task forces.

Only about 25% of the FoT teachers attended either a state or a national T&E conference within the past three years, which was greater than the 9% who attended a similar science conference. When attending these events,

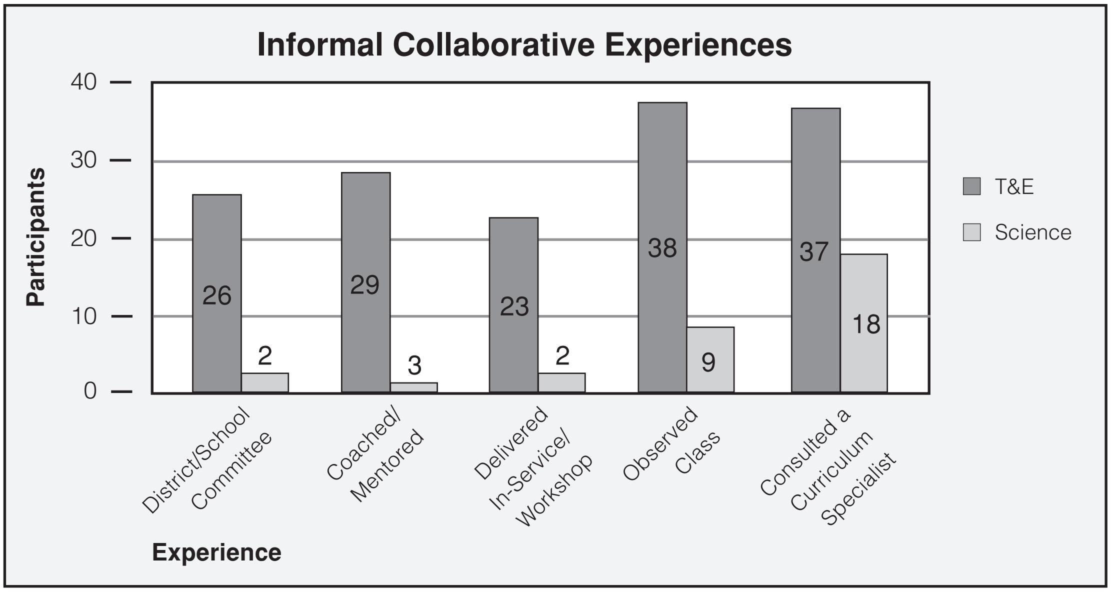

Figure 7. Summary of participants' informal collaborative experiences.

teachers reported attending mostly T&E sessions (35%); however, 18% attended sessions focused on both science and T&E topics. No participants attended sessions focused mainly on science concepts (Table 6).

Participants collaborated with other T&E teachers most frequently, with 36% reporting that they work with these individuals on a daily basis. FoT teachers did not collaborate with physics, biology, or math teachers as often that school year. In fact, 65% reported never collaborating with biology teachers, while slightly more than half (51%) claimed they never collaborated with their school's physics instructor (Figure 8).

Table 6: *Summary of Conferences and Sessions Participants Attended*

Function Attended		n (%)
Conference		
	State or ntl. science	5(9)
	State or ntl. T&E	15(27)
Session		
	Science	0(0)
	T&E	19(35)
	Science and T&E	10(18)
	Unsure	25(46)

Note. Ntl. = national

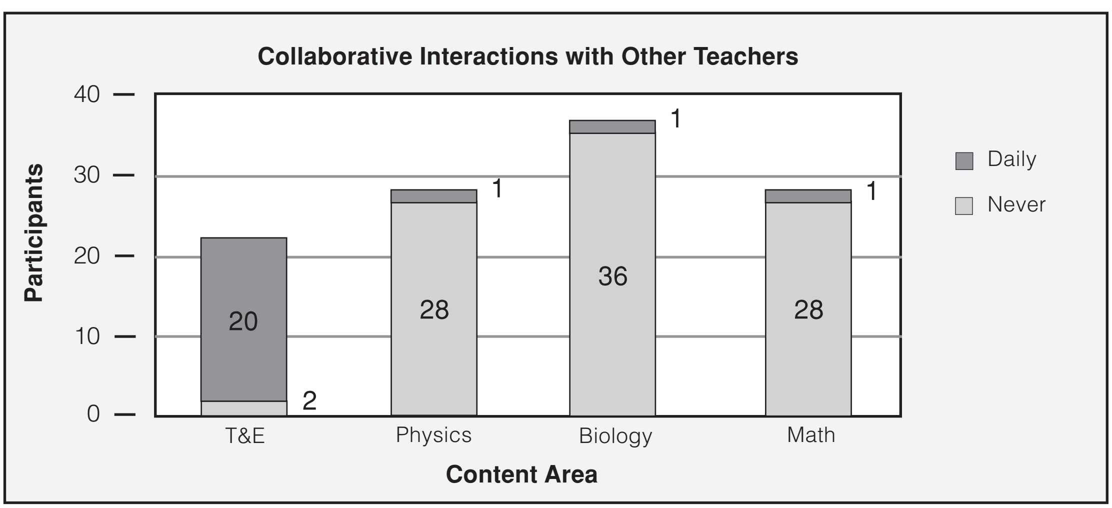

Figure 8. Summary of how frequently participants collaborated with other teachers.

DISCUSSION

The data presented in the findings section help paint a broad picture of the average demographic and preparation experiences of those 55 individuals teaching FoT within 12 school systems of one EbD consortium state. Although the findings provide a general overview of these specific T&E educators, they cannot be generalized to T&E educators in other school systems, states, or who are teaching different curricula. Despite these delimitations, the findings do aid in drawing important conclusions about the participating T&E educators. The remainder of this section discusses the similarities between the findings from this research and larger national studies.

Moye, Jones, and Dugger (2015) conducted a national study examining the status of T&E education among states. In addition, Ernst and Williams (2014) conducted research using the Schools and Staffing Survey, a standardized national reporting data set from the U.S. Department of Education and the National Center for Education Statistics (NCES). This data set examined the demographics, characteristics, and qualifications of 50,606 individuals teaching T&E education in K-12 school districts across the U.S. Table 7 compares the findings among these previous research efforts and this study.

Table 7: *Comparison of Demographic and Preparation Data Among Studies*

	Moye, Jones, & Dugger (2015)	Ernst & Williams (2014)	Love (2015)
Ethnicity (%)			
Caucasian	NR	92	93
African American	NR	5	2
Asian	NR	2	2
Gender (%)			
Male	77.2	75.4	73
Female	22.8	24.6	27
Age (μ)	NR	47	43
Years Teaching (μ)	NR	15.5	13
Degree (%)			
Bachelors	NR	54	24
Master’s	NR	40	44
Ed.S	NR	4.6	0
Doctorate	NR	1	4
Certified to Teach T&E	NR	86	84
Qualification (%)			
Highly Qualified	NR	59	NR
Not Highly Qualified	NR	25	NR
Preperation (%)			
Teacher Prep Program	NR	78	73
Alternative Licensure	NR	22	17

Note. NR = Not reported; Ed.S. = Education Specialist

The consistency among these three studies indicates that the majority of T&E education teachers in the U.S. are Caucasian males in their mid to late 40s, who have completed a teacher preparation program, are certified to teach T&E education, and have been teaching on average for approximately 14 years (Table 7). The lack of women and minorities in STEM fields is a critical issue within the U.S. One method for addressing this shortage is to recruit more women and minority role models to teach P-12 T&E education (Ilumoka, 2012).

One interesting finding that emerged from this study is the variety of content areas in which participants held degrees. Less than 70% held a bachelor's or master's degree in technology education, and 17% held similar degrees in industrial arts. What was most alarming was the amount of participants (17%) teaching FoT who held a degree in business education or physical education, and the fact that only 84% of the teachers were certified to teach T&E education.

The results from this study were also consistent with Strimel's (2013) examination of coursework completed by FoT teachers across four states, which revealed FoT teachers completed a broad scope and limited amount of college science coursework (Table 8).

Table 8: *Comparison of Higher Education Science Courses Completed Among Studies*

Completed ≤ 2 Courses In	Strimel (2013) (%)	Love (2015) (%)
Physics	23	27
Biology	26	27
Chemistry	23	15
Environmental or Earth Science	19	7

When examining the data regarding completed high school courses, physics was taken the least (Figure 3). The findings from the full data analysis of this population (Love, 2015) revealed that high school science courses, especially physics, had the strongest correlation with the level at which T&E educators' taught embedded science concepts. Additionally, FoT and many other T&E courses (e.g. EbD-TEEMS, EbD Advanced Design Applications, EbD Advanced Technological Applications, Project Lead the Way) are naturally intertwined with physics. For example, in Units 3 and 4 of the FoT curriculum, instructors are expected to teach how science concepts, such as thermodynamics, atomic structure, nuclear energy, energy loss and conservation, and electron flow can be applied to solve technological problems. However, given the minimal amount of high school and college physics courses teachers completed, most exhibited a difficult time integrating and teaching these concepts proficiently (Love, 2015). For the aforementioned reasons, it is imperative that students interested in pursuing a career as a T&E educator be advised to complete a minimum of one physics course in high school to experience how physics concepts are taught at the secondary level.

In both Strimel's (2013) research and this study, it was determined that less than a quarter of teachers completed two or more college courses in physics, biology or chemistry (Table 8). In the full data analysis (Love, 2015), college physics courses also showed a strong correlation with how proficient FoT instructors were at teaching science concepts embedded within the curriculum. Litowitz (2013, 2014) found that 42% of T&E programs required students to complete one physics course, and only 4% required students to complete two physics courses. Because of the findings from the full study and the natural application of physics concepts to solve technological design problems, T&E educators should complete not one, but two college physics courses with labs. This study also revealed a lack of undergraduate biology (27%) and biotechnology (18%) courses completed by participants. More T&E teacher preparation programs should require students to complete a course and lab in biology so they have greater content knowledge about biological concepts they are expected to teach in medical, agricultural, and biotechnology units according to the *Standards for Technological Literacy* (ITEA/ITEEA, 2000, 2002, 2007).

From the informal experiences it was clear that participating FoT teachers partook in far more T&E than science related activities. This was apparent from the literature they read, to their participation in workshops, school committees, online networks, and conferences. The high percentage of participants attending mostly T&E conference sessions was also consistent with previous research (Love & Loveland, 2014). The T&E and science educator associations in Maryland created a collaborative professional development opportunity by merging their annual conferences. From this experience, attendees reported gains in their understanding of content and ability to demonstrate concepts from both within and outside of their content area. Some attendees at this conference also reported that simply eating lunch and attending sessions with educators outside of their content area spawned integrative conversations and relationships (Love & Loveland, 2014).

Given the alignment of the data from this study with other recent national studies (Ernst & Williams, 2014; Love & Loveland, 2014; Moye, Jones, & Dugger, 2015; Strimel, 2013) it could be expected that T&E educators from other states would have similar demographics and preparation experiences to those reported in this study.

CONCLUSIONS

By no means does this study suggest that the participating FoT teachers be tasked with teaching science content and practices in lieu of science educators; rather it exposes the importance of preparing them with the baseline content and pedagogical knowledge to explicitly make integrative connections and work collaboratively with science educators to reinforce these concepts. Because of the large amount of T&E content and pedagogical preparation needed to adequately teach the FoT curriculum, perhaps the most viable method for teaching embedded STEM concepts with the greatest amount of integration is to work collaboratively with science teachers (Wells, 2008). Drake and Burns (2004) provide some excellent integrative instructional models that can be utilized by P-12 STEM education programs.

Given the increasing demand on FoT teachers to prepare more STEM-literate citizens, and the continually convergent paths of T&E and science education (Love & Loveland, 2014), the lack of science courses completed by participants was alarming. In Litowitz's (2014) analysis, he noted that courses covering content foundational to the STLs, such as medical, agricultural, and related biotechnologies, were absent from T&E teacher preparation programs' requirements. With the STLs placing an emphasis on teaching concepts from these science-related areas, it would be logical for FoT teachers to complete an ample amount of science content courses in their preparation. This would be expected to increase their content knowledge needed for making integrative connections between science and T&E concepts when teaching the FoT units. Teacher educators are challenged with finding room in already crowded T&E teacher preparation curricula for such courses. This is a delicate balance that must be addressed to better prepare T&E educators, specifically FoT teachers, for teaching STEM concepts.

In addition to the raw data, one of the important contributions of this study to Integrative STEM Education is a unique instrument – the TEES-PCK survey. It could be used or modified for future studies when authors are considering collecting detailed demographic and preparation data. Specifically, the TEES-PCK could easily be utilized to collect data for studies in other disciplines, such as examining science educators' preparation to teach engineering content and practices.

RECOMMENDATIONS

A number of recommendations for practitioners and researchers were derived from this study. Given the limited percentage of FoT teachers from diverse populations, more of these individuals must be recruited to teach FoT, whether through teacher preparation or alternative licensure programs. These individuals could, in turn, serve as role models to recruit additional students from diverse populations to become T&E educators and pursue STEM-related careers (Ilumoka, 2012; Moye, Jones, & Dugger, 2015).

When analyzing the TEES-PCK results, it became apparent that many teachers had started the survey but failed to finish. When reminded about completing it, teachers expressed that the length and detail of the instrument discouraged them from finishing it. For this reason, it is recommended that when using the TEES-PCK in future studies, researchers only use those questions for which they are seeking data. This would decrease the amount of time requested from teachers and be expected to increase participation. Furthermore, because all T&E educators are expected to integrate content from various disciplines (ITEA/ITEEA, 2000/2002/2007), the TEES-PCK should be used in future studies to examine the preparation factors of the broader T&E educator population.

The findings also revealed that FoT teachers participated in far less science than T&E preparation experiences, and a limited amount of opportunities to collaborate with science educators. The full study results (Love, 2015) found that many of these integrative experiences with science educators had a positive influence on the extent to which participants' taught science concepts. Therefore, it is recommended that administrators and school systems provide more accessible integrative professional development opportunities between FoT and science educators to help foster collaborative relationships. Lastly, as T&E teacher preparation programs aim to prepare educators who can integrate STEM concepts more proficiently, they should use the reported findings to inform changes in pre-service coursework requirements. The significance that each course had on the teaching of science content and practices can be found in the full study (Love, 2015).

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Evaluation of a Nuclear Energy Production Technology Program

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ABSTRACT

This study investigated the perceptions held by key individuals within the energy industry involved in the development of an Energy Production Technology degree program at a Midwest community college to help address the need for qualified workers for the local nuclear power plants. Through open-ended interviews and surveys, the mixed methods case study collected data from 34 Energy Production Technology (EPT) program graduates, seven EPT program advisory committee members, and four employers of graduates in the energy industry. The findings revealed that the program was successful for creating a supply of qualified technicians; the employers and graduates equally believed that the program adequately prepared technicians for employment. Lessons learned include having a realistic labor projection and knowledge of employability requirements, and making sure all the right stakeholders are involved in the program development process. The study has implications for policy and practice in career and technical education, especially for those who work closely with industry.

Key words: energy industry training, program evaluation, community college

PROJECT BACKGROUND

According to the Nuclear Energy Institute (NEI) over one-third of the current workforce in the industry may be retiring within the next five years, which will require training and hiring about 25,000 new workers (NEI, 2010). To address the projected shortage of energy industry professionals for the region it serves, the community college in this study, through a partnership with the local energy industry, developed an Energy Production Technology degree program to give local individuals looking for employment the opportunity to prepare for high-skilled, high-wage jobs in the energy field. Due to feedback from local energy employers, the community college was sought out, because, historically, the commercial nuclear industry counted on the U.S. Navy to provide technicians for civilian jobs, but the size of this group has decreased over the years while the demand has increased.

This program was developed in part by following the curriculum outline that was established by the Nuclear Uniform Curriculum Program (NUCP) created in 2007 by NEI. The NUCP was created as a quasi-accreditation process to guide community colleges to help power plants staff their future workforce, and it is a standardized program for educating operators and technicians for jobs at nuclear plants (NEI, 2010). Based on a review of the literature, prior to 2007, there is little evidence of a concerted effort between nuclear power plants and community colleges to engage in such a partnership. The NUCP program requires a common curriculum regarding plant equipment and systems, science and mathematics, and technical electives in a student's chosen focus area (chemistry, operations, health, physics, radiation protection, and maintenance).

Regardless of NEI involvement, prior to the development of an energy-focused program, one of the concerns often unfamiliar to any college that attempts to develop such a degree program is that the power production industry is highly regulated. According to Laraia and Dlouhy (1999), "the laws and regulations are often complex and overlapping, involving several government ministries, departments, and/or agencies. These laws and regulations typically provide licensing of various aspects of the nuclear industry, government oversight, setting of standards (both technical and environmental), and protection of human health from radiological (and other) hazards" (p. 40). Safety is a preeminent concern in the nuclear industry, not only for its own sake, but also because of its sensitivity in terms of public perception and, formally, because of national and regional regulations and international agreements (Organisation for Economic Cooperation and Development [OECD], 2012). Local Energy partners supported this, by characterizing the importance of a high level of education and training to maintain the level of safety necessary for the plants to run successfully.

RATIONALE FOR THE STUDY

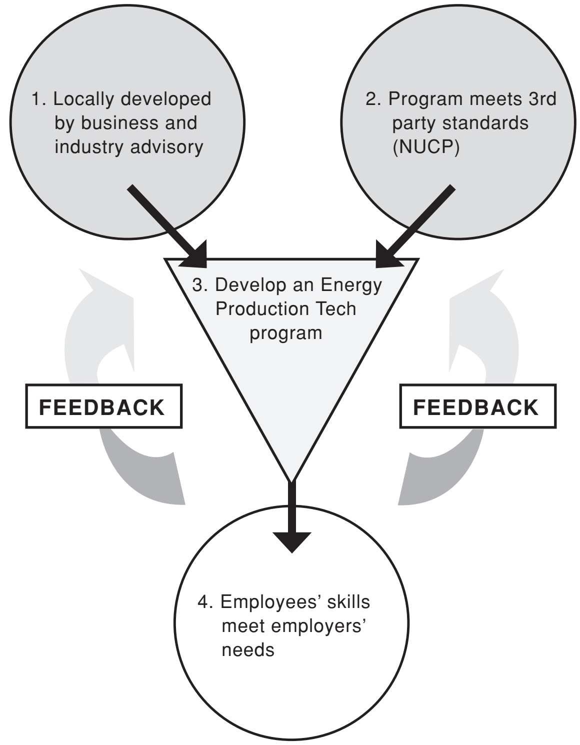
The purpose of this research was to determine the perceived success of the new Energy Production Technology program created in partnership with a community college and its local business and industry service district. It was essential to assess the feedback process within this partnership to determine if the program was yielding effective results as perceived by program graduates and their employers. Equally important was to determine the role played by the advisory committee that was developed to implement and provide oversight to the program.

A principal goal of community colleges is to ensure that the workers in the region they serve have the educational tools needed to survive in today's job market (Government Accountability Office, 2008). In order for any degree program to remain viable and relevant, it must prepare highly skilled individuals who are aligned with the changing needs of a given industry. To do this, the labor force and educational organizations should be structured around integrated education, training, and program evaluation processes (Government Accountability Office, 2008). For employers, this extended effort provides opportunities for recruiting and training new employees, additional skills for incumbents, and potentially improving retention.

Assessing the success of a program is vital to provide the best service to stakeholders. According to Epstein, Coates, Wray, and Swain (2006), "The stakeholder's role is broader than being a customer of services, because the conditions citizens experience in the community and in their lives are affected by many things other than community services" (p. 27). Success depends entirely on how community colleges, along with their region's stakeholders, can effectively collaborate and bring collective resources to bear on the challenges facing them. Yet there is little published research on the evaluation of technical programs at this level (Zinser, 2003).

CONCEPTUAL FRAMEWORK

As graduates become employed in the industry, it is important to evaluate the validity of the training that is provided by the college. A continual feedback loop of evaluation and improvement should be developed as both the college and industry review and adjust perceived curriculum and employment outcome gaps.



Locally Developed by Businessand Industry Advisory Committee

When developing a new program at any college, there must be coordination across key state, local, and stakeholder agencies. According to a report by MPR Associates (2010), "Development of programs of study includes analysis of current labor market information to determine which programs of study will truly result in high demand jobs, input from stakeholders that is genuine and sustained, and funds dedicated to both initial development of POS as well as sustenance through curriculum development and business and education input" (p. 15). Once these pertinent data are collected and reviewed, if validated, local business and industry partners in the community convene to form a program advisory committee to cultivate the program.

Program Meets Third Party Standards (NUCP)

A key benefit of the NUCP is that once graduates who earn this certificate are hired at the plant, they can be waived or exempted from portions of required initial training. By evaluating and accrediting the community college training programs, this waiving or exemption of training is a cost-saving measure for the power plants allowing the plants to then redirect those financial resources to other areas. Organizing industry partnerships with two-year education programs helps leverage resources to provide the next generation of highly skilled workers (NEI, 2010).

Develop an Energy Production Technology Program

The strengths of the program developed by the internal analysis included strong support from the local power generation industry, industry-experienced adjunct instructors, strong base of potential workers due to manufacturing shortages, NEI pilot program, and strong government (and public) support for renewable energy. These strengths support the framework focus centered around the advisory committee (strong support from local industry), third-party program review process (NEI pilot) program, and adequately prepared employees (strong base of potential workers).

Employees' Skills Meet Employers' Needs

One of the key intents of the Energy Production Technology program is to prepare students to enter the workforce in an energy production area while also increasing the skills of those already in the workforce. In order to continue to meet these employer needs, as the program matures, it is important to sustain a feedback continuum in order to maintain program relevancy. For example, at the early stages of program development, based on feedback from employers and students, a key component missing from the program that limited students' preparedness was that the college did not have lab equipment or a recognized lab space for one of the hands-on technical programs. Gaps were identified through instructor and student surveys that revealed this limited access to equipment. Initially, to use appropriate equipment, instructors would either schedule time at the plant or bring pieces to the class for students to use. This, at times, caused logistical issues for both students and the instructors.

METHODS AND PROCEDURES

Three research questions formed the basis for this study to examine issues surrounding the Energy Production Technology program. The intent was to: (1) determine the perceptions of the advisory committee participants regarding their role with the program including questions about curriculum, equipment, facilities, and job placement; (2) understand the perceptions of employers regarding how the college program prepared students for employment in the energy field; and (3) ascertain program graduates' perceptions about how the college program readied them for employment in the energy field and to provide a reflection of their scholastic experience at the college.

This research used a mixed method, case study approach as the strategy of inquiry. Characterized by its exploratory nature, this type of research seeks a more in-depth, detailed, and close-up view of a topic, collecting data with questions that typically begin with "how" or "what" (Creswell, 1998) and expressing data using words rather than numbers. The method provides opportunities to interact with subjects on a human-to-human basis, to explore further, if necessary, using follow-up questions, and to arrive at conclusions post hoc rather than a priori (Creswell, 1998; Lancy, 1993). Additionally, online surveys were used to understand the perceptions of the program graduates. Data was analyzed and organized into themes and patterns consistent with the conceptual framework.

Selection of Subjects

Purposeful sampling is a technique widely used in mixed methods research for the identification and selection of information-rich cases for the most effective use of limited resources (Patton 2002). This involves identifying and selecting individuals or groups of individuals who are especially knowledgeable about, or experienced with, a phenomenon of interest (Creswell & Plano Clark, 2010). The population in the study included individuals (students, advisory committee members, and energy employers) who were currently participating in, or who had recently participated in, the college's EPT program, as noted below:

> **Group One:** Former and current advisory committee members (2008-present) who helped establish and continue oversight of the program. (N = 7; interview)
>
> **Group Two:** Energy production employers who have hired graduates from the program. (N = 4; interview, skills checklist)
>
> **Group Three:** Students who had graduated from the EPT during the life of the program (2008-present). (N = 34; survey)

Personal interviews were conducted with group one, the seven individuals who had or still continue to participate in the advisory committee, to capture their perceptions of the program development and implementation. To address research question number one, advisory committee participants were asked their perceptions regarding their role with the program, including questions about curriculum, equipment, facilities, and job placement.

Personal interviews were also conducted with group two, the four individuals at the power plants who have hired graduates from the college's energy program. To address research question number two, these participants were asked their perceptions about how the college program prepared students for employment in the energy field. Included as part of the interview process, these individuals were also asked to complete a skills checklist that examined the specific skill sets of the graduates they have hired.

An online survey was developed to understand the perceptions of the students who graduated from the program (group three). To address research question number three, program participants were asked their perceptions about how the college program readied them for employment in the energy field and to provide a reflection of their scholastic experience at the college. Based on graduation data received from college records, 125 potential program graduates were available for the survey. An email request was sent out, as well as follow-up reminders, which yielded 34 participants out of 115 (10 addresses were undeliverable) for a 30% response rate. Descriptive statistics were used to summarize and analyze the survey data.

Once all data was sorted and reviewed, patterns began to materialize. A theme such as "nuclear culture" for example, was created to facilitate additional layers of complex analysis. The interpretation of data also required a basic understanding of human behavior as it was important to interpret each individual's explanation. Additional analysis was completed in order to have the interview evidence validated. "In qualitative research, validation has focused on assessing how well participants' meanings have been captured and interpreted" (Ritchie & Lewis, 2013, p. 358). This method is known as respondent validation (or member checking), which involved returning to the study participants of both Groups One and Two and asking them to validate the analyses (Burnard, Gill, Stewart, Treasure, & Chadwick, 2008, para. 19). The interview subjects were provided transcripts of the interview and asked to review the account as deduced by the researcher, to make sure their narrative was accurately applied.

FINDINGS

While reviewing the interview transcripts, common statements or expressions that appeared to be connected to the research questions were highlighted, coded, and grouped into themes using the reduction process. For example, statements that were coded as "developing a local hiring pool" were grouped with other significant topics coded as "lack of trained individuals," "entry-level candidates," and "looking for employable people" into a larger theme coded as "creating a qualified workforce." Each significant point from the transcripts of the employers and the advisory committee were coded using a similar framework as the example listed above. Through the raw data collected from the employers three themes emerged, whereas the advisory committee interviews fostered four themes. In reporting the findings, names and other identifying factors of the subjects have been restricted; if a name was needed to improve readability, a pseudonym or alias was used.

Research Question One

During the interview process, study participants were asked to reflect on their experiences as an advisory committee member, why they felt it was important to participate in the program, describe the NUCP feedback loop, describe the impact to the workforce, provide lessons learned and reflect on significant experiences. Analysis of the interview data provided dominant themes that participants viewed as significant factors regarding their participation in the program's advisory committee as described below.

Theme one: Program has created qualified workers. Based on the perspective of developing competent workers coupled with the perceptions of mass retirements, the advisory committee commented favorably that the college did indeed offer a supply of qualified technicians with at least 45 of the 125 program graduates presently employed in the local energy industry. According to Stanley (subject 2, personal interview, July 6, 2015), a college representative, "I think it's been huge. I mean look at the number of graduates who are working at the local plants . . . before this program, we had nothing."

Theme two: Be sure to involve the right stakeholders. Despite getting key stakeholders on the advisory board, not having the right person from all levels within the industry did impact the effectiveness of the feedback loop for the NUCP process among the committee, employer, and student. Mark (subject 3, personal interview, July 7, 2015) for example stated that, "Feedback wise, to be honest, I really wish we would add more stake from a management level... it seemed like there was a lot of in-between that lacked getting information from a real stakeholder." In other words, based on this feedback, because of the lack of stakeholder involvement regarding student results, some outcomes were not addressed, and it sometimes hurt the reputation of the program.

Theme three: Program not adequately preparing graduates to pass the pre-employment test. The nuclear energy industry utilizes pre-employment testing on certain jobs to identify and assess a candidate's abilities and skills. When the program was first developed, the concept of pre-employment testing was not an issue strongly discussed by the advisory committee--it was an afterthought. Also, students were vaguely aware of the process, and the curriculum was not developed so they could easily transition into successful pre-employment exams; therefore, many students were not prepared for such tests. This was a consistent concern among all three groups (students, employers, and advisory committee). Larry (subject 1, personal interview, July 1, 2015) felt quite strongly regarding this as he stated that, "The biggest gap that I saw for the entire time I was there, and I would be surprised if it's not still a gap today, was the mathematics to prepare the students for the MASS/POSS test" (the pre-employment exam).

Theme four: Need a better understanding of balance between labor supply and demand. During the development process the college faced significant challenges to help "create a market"—that is, to not simply harvest a supply of degrees, but to also influence the demand for those degrees. Another concern was that "labor demand" included some positions that did not require a degree and therefore inflated the plants' estimates of the number of new hires needed. Founded on the lack of a more in-depth environmental scan and needs analysis, it was better understood that it was probably irresponsible to let the program increase to 230 students. Larry (pseudonym) suggested that:

> My biggest advice is to watch your numbers. We kind of were told that by some people up front. In retrospect we probably should pay more attention to that. Watch the numbers based on the demand in the local community and basically put a cap on the number of people that are in the program.

Based on the disappointment from those that could not find employment in the industry, making sure to have the right balance of labor supply and demand is critical.

Research Question Two

During the interview process, employers who hired the graduates were asked to reflect on whether the EPT program prepared students for a career in the energy industry, how they compared to other school's graduates, what skills they were best or least equipped with, and what additional advice they could provide to the college to help strengthen the program. Analysis of the interview data provided dominant themes that participants viewed as significant factors regarding the college's program preparing students for employment in the energy field.

Theme one: Students are well prepared on core technical skills. Based on both the interview responses and the replies to the skills checklist, employers from each plant agreed that EPT graduates have the core technical skills necessary to work in the energy industry. Evan (subject 4, personal interview, July 30, 2015) from Plant A stated, "They're good at what they do. They came into the training class here from the courses and I think that gave them a good leg-up for the next level. The plant specific, system specific things."

Theme two: Individuals from the military are better prepared. When asked how EPT graduates from the college compare to those graduates from other technical programs (military other colleges), all respondents collectively stated that the people in the military had an advantage. A key theme that should be pointed out from these statements is that "it isn't because of the schooling," it is ingrained in the military recruits because it has been their job.

Theme three: The program should better prepare students for the "nuclear culture."
In Table 1 of the skills checklist response, employers of EPT graduates moderately agreed that graduates were prepared. However, what the skills checklist did not identify that what the interviews included was the concept of preparedness for an employee in the nuclear field. When asked about some shortcomings of EPT graduates, Evan (pseudonym) stated," Probably just the difference in our industry and how we do business. We have very strict guidelines on how to work through [any] procedure" (in the nuclear environment).

Employers filled out a skills' checklist based on a review of the program's guidelines regarding the students' preparedness. Tables 1-3 display the respondents' answers to questions regarding graduates' skills preparedness, core fundamentals preparedness, and overall preparedness. The total mean scores in Table 1 ranged from 4.50 – 5.50. Overall the employers moderately agreed that the graduates had the necessary core skills. It should be noted that the lower standard deviation (SD) would generally mean that there was significant alignment among the respondents' answers; however, the small number of individuals interviewed (n = 4) drastically affects the confidence interval of this data.

The mean scores for Nuclear Uniform Curriculum Program (NUCP) core fundamentals preparedness (see Table 2) were above the mid-point, with a range of 4.00 – 5.25. The highest skill score was "Computers (plant specific)," and the lowest was a tie among three topics: "Electrical Sciences," "Heat Transfer and Fluid Flow" and "Chemistry." All four supervisors scored these topics equally.

On the skills checklist, question 3 asked about overall preparedness. The total mean score on this topic was 5.25, which indicates moderate agreement (Table 3).

To summarize the responses to research question number 2, overall the four employer respondents believed that graduates of an Energy Production Technology program were prepared for employment. They did believe the graduates could use some work being prepared for the nuclear culture, an area in which they believed military recruits had an obvious advantage.

Research Question Three
The third research question sought perceptions from the energy program's graduates regarding how the college program readied them for employment in the energy field, and to provide a reflection of their scholastic experience at the college. A survey tool based on a review of program guidelines was used to gather

Table 1: *Employers' Perceptions of Graduate Skills Preparedness*

Question	Disagree Strongly n (%)	Disagree Moderately n (%)	Disagree Slightly n (%)	Agree Slightly n (%)	Agree Moderately n(%)	Agree Strongly n (%)	Mean	SD
Overall, program prepared graduates hired for these job skills:								
Successfully demonstrate safe work habits	0(0.0)	0(0.0)	0(0.0)	0(0.0)	4(100.0)	0(0.0)	5.00	0.00
Successfully work in teams	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(50.0)	2(50.0)	5.50	0.50
Successfully work independently	0(0.0)	0(0.0)	0(0.0)	1(25.0)	2(50.0)	1(25.0)	5.00	0.71
Successfully solve complex problems	0(0.0)	0(0.0)	0(0.0)	2(50.0)	2(50.0)	0(0.0)	4.50	0.50
Document clearly and effectively	0(0.0)	0(0.0)	0(0.0)	2(50.0)	2(50.0)	0(0.0)	4.50	0.50
Communicate clearly and effectively	0(0.0)	0(0.0)	0(0.0)	1(25.0)	2(50.0)	1(25.0)	5.00	0.71

Note. Likert Scale = Disagree Strongly (1), Disagree Moderately (2), Disagree Slightly (3), Agree Slightly (4), Agree Moderately (5), Agree Strongly (6).

Table 2: *Employers' Perceptions of Nuclear Uniform Curriculum Program (NUCP) Core Fundamentals Preparedness*

Question	Disagree Strongly n (%)	Disagree Moderately n (%)	Disagree Slightly n (%)	Agree Slightly n (%)	Agree Moderately n(%)	Agree Strongly n (%)	Mean	SD
Overall, program successfully prepared graduates with these NUCP core fundamentals:								
Mathematics	0(0.0)	0(0.0)	0(0.0)	1(25.0)	3(75.0)	0(0.0)	4.75	0.43
Physics	0(0.0)	0(0.0)	0(0.0)	3(75.0)	1(25.0)	0(0.0)	4.25	0.43
Electrical Sciences	0(0.0)	0(0.0)	0(0.0)	4(100.0)	0(0.0)	0(0.0)	4.00	0.00
Basic Atomic and Nuclear Physics	0(0.0)	0(0.0)	0(0.0)	2(50.0)	2(50.0)	0(0.0)	4.50	0.50
Heat Transfer and Fluid Flow	0(0.0)	0(0.0)	0(0.0)	4(100.0)	0(0.0)	0(0.0)	4.00	0.00
Chemistry	0(0.0)	0(0.0)	0(0.0)	4(100.0)	0(0.0)	0(0.0)	4.00	0.00
Properties of Reactor Plant Materials	0(0.0)	0(0.0)	0(0.0)	3(75.0)	1(25.0)	0(0.0)	4.25	0.43
Radiation Detection and Protection	0(0.0)	0(0.0)	0(0.0)	1(25.0)	3(75.0)	0(0.0)	4.75	0.43
Reactor Plant Protection and Safety	0(0.0)	0(0.0)	0(0.0)	2(50.0)	2(50.0)	0(0.0)	4.50	0.50
Computers (Plant Specific)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(75.0)	1(25.0)	5.25	0.43
Basic Systems Knowledge	0(0.0)	0(0.0)	0(0.0)	2(50.0)	2(50.0)	0(0.0)	4.50	0.50
Basic Components Knowledge	0(0.0)	0(0.0)	0(0.0)	2(50.0)	2(50.0)	0(0.0)	4.50	0.50

Note. Likert Scale = Disagree Strongly (1), Disagree Moderately (2), Disagree Slightly (3), Agree Slightly (4), Agree Moderately (5), Agree Strongly (6).

Table 3: *Employers' Perceptions of Students' Overall Preparedness*

Question	Disagree Strongly n (%)	Disagree Moderately n (%)	Disagree Slightly n (%)	Agree Slightly n (%)	Agree Moderately n(%)	Agree Strongly n (%)	Mean	SD
Overall, the Energy Production Technology Program has:								
Successfully prepared the graduates I have hired for a career in the energy industry	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(75.0)	1(25.0)	5.25	0.43

Note. Likert Scale = Disagree Strongly (1), Disagree Moderately (2), Disagree Slightly (3), Agree Slightly (4), Agree Moderately (5), Agree Strongly (6).

Table 4: *Students' Perceptions of Instructional Content and Program Quality*

Question 3	Employed Y or N	Disagree Strongly n (%)	Disagree Moderately n (%)	Disagree Slightly n (%)	Agree Slightly n (%)	Agree Moderately n(%)	Agree Strongly n (%)	Mean	SD
Instructional content and quality program were to provide me with strong practical job application experience.									
	Yes (n=18)	0(0.0)	1(5.5)	1(5.5)	0(0.0)	8(44.4)	8(44.4)	5.17	1.07
	No (n=16)	2(12.5)	1(6.3)	2(12.5)	1(6.3)	8(50.0)	2(12.5)	4.13	1.58
	Tot. (n=34)	2(5.9)	2(5.9)	3(8.8)	1(2.9)	16(47.1)	10(29.4)	4.68	1.43

Note. Likert Scale = Disagree Strongly (1), Disagree Moderately (2), Disagree Slightly (3), Agree Slightly (4), Agree Moderately (5), Agree Strongly (6).

Table 5: *Students' Perceptions of Job Skills Preparedness*

Question 3	Employed Y or N	Disagree Strongly n (%)	Disagree Moderately n (%)	Disagree Slightly n (%)	Agree Slightly n (%)	Agree Moderately n(%)	Agree Strongly n (%)	Mean	SD
Overall, program prepared me for the job skills:									
Successfully demonstrate safe work habits	Yes (n=18)	0(0.0)	0(0.0)	2(11.1)	5(27.8)	4(22.2)	7(38.9)	4.89	1.05
	No (n=16)	0(0.0)	0(0.0)	2(12.5)	3(18.8)	4(25.0)	7(43.8)	5.00	1.06
	Tot. (n=34)	0(0.0)	0(0.0)	4(11.8)	8(23.5)	8(23.5)	14(41.5)	4.94	1.06
Successfully work in teams	Yes (n=18)	0(0.0)	0(0.0)	1(5.6)	3(16.7)	3(16.8)	11(68.8)	5.33	0.94
	No (n=16)	0(0.0)	0(0.0)	3(18.8)	2(12.5)	4(25.0)	7(43.8)	4.94	1.14
	Tot. (n=34)	0(0.0)	0(0.0)	4(11.8)	5(14.7)	7(20.6)	18(52.9)	5.15	1.06
Successfully work independently	Yes (n=18)	0(0.0)	0(0.0)	1(5.6)	3(16.7)	5(31.3)	9(56.3)	5.22	0.92
	No (n=16)	0(0.0)	0(0.0)	3(18.8)	2(12.5)	4(25.0)	7(43.8)	4.94	1.14
	Tot. (n=34)	0(0.0)	0(0.0)	4(11.8)	5(14.7)	9(26.5)	16(47.1)	5.09	1.04
Successfully solve complex problems	Yes (n=18)	0(0.0)	0(0.0)	1(5.6)	4(22.2)	5(27.8)	8(44.4)	5.11	0.94
	No (n=16)	1(6.3)	0(0.0)	2(12.5)	2(12.5)	4(25.0)	7(43.8)	4.81	1.42
	Tot. (n=34)	1(2.9)	0(0.0)	3(8.8)	6(17.7)	9(26.5)	15(44.1)	4.97	1.20
Document clearly and effectively	Yes (n=18)	0(0.0)	0(0.0)	2(11.1)	3(16.8)	6(33.3)	7(38.9)	5.00	1.00
	No (n=16)	1(6.3)	1(6.3)	2(12.5)	1(6.25)	4(25.0)	7(43.8)	4.69	1.57
	Tot. (n=34)	1(2.9)	1(2.9)	4(11.8)	4(11.8)	10(29.4)	14(41.1)	4.85	1.31
Communicate clearly and effectively	Yes (n=18)	0(0.0)	1(5.6)	1(5.6)	2(11.1)	7(38.9)	7(38.9)	5.00	1.11
	No (n=16)	1(6.3)	0(0.0)	2(12.5)	2(12.5)	3(18.8)	8(50.0)	4.88	1.45
	Tot. (n=34)	1(2.9)	1(2.9)	3(8.8)	4(11.8)	10(29.4)	15(44.1)	4.94	1.28

Note. Likert Scale = Disagree Strongly (1), Disagree Moderately (2), Disagree Slightly (3), Agree Slightly (4), Agree Moderately (5), Agree Strongly (6).

information about graduates' perceptions both in school and if applicable, at subsequent employment, regarding if they believed they were prepared for employment. It was important to investigate what this new program's experience meant to the participants, and to determine what they believed to be the strengths and weaknesses of the program, based on both their perceptions of their experience and ability to be employed. The survey was comprised of 20 questions using a six-point Likert scale, and it included three open-ended questions regarding their perceptions of the program.

For question 3 of the survey, respondents were asked about *instructional content and program quality.* The results presented in Table 4, are broken down by those employed in the industry, those not employed in the industry, and the overall total.

The total mean score regarding instructional content and program quality was moderately high at 4.68. Over 78% of the students moderately agreed that the curriculum was designed to provide them with strong, practical job application experience. This number is based on an average that included students who stated they were working in the energy industry and those who were not. For students with jobs (N = 18) in the energy field, 89% of them felt the program content and quality was solid, whereas for students without such jobs (N = 16) 69% agreed. It is important to note that a pattern was revealed throughout this survey that the mean scores from students who did not attain a position in the energy field was much lower on average than students who did gain a position, and this lowers the total mean substantially. The mean scores regarding instructional content and program quality came in at 5.71 for student with jobs in the energy field and 4.13 for students who did not gain employment in this field. However the sample size is not large enough to establish statistical significance.

The mean scores regarding job skills preparedness in Table 5 were quite high with a range of 4.85 – 5.15. The highest skill score was "successfully work in teams" and the lowest was "document clearly and effectively": all other statements had a mean score over 4.8. More than 87% of the students felt that they had the appropriate job skills to work in the energy field. Significantly, even the students who did not have jobs in the energy field still felt very prepared by the program to work in energy by an average of 81%.

The mean scores for Nuclear Uniform Curriculum Program (NUCP) core fundamentals preparedness were above average with a range of 4.26 – 5.44. The highest skill score was "properties of reactor plant materials," and the lowest was

Table 6: *Perceptions of Nuclear Uniform Curriculum Program (NUCP) Core Fundamentals Preparedness*

Question 3	Employed Y or N	Disagree Strongly n (%)	Disagree Moderately n (%)	Disagree Slightly n (%)	Agree Slightly n (%)	Agree Moderately n(%)	Agree Strongly n (%)	Mean	SD
Overall, program prepared me to meet these Nuclear Uniform Curriculum Program (NUCP) core fundamentals:									
Mathematics	Yes (n=18)	0(0.0)	0(0.0)	1(5.9)	1(5.9)	6(33.3)	9(50.0)	5.28	0.87
	No (n=16)	1(6.3)	1(6.3)	2(12.5)	2(12.5)	6(37.5)	4(25.0)	4.44	1.46
	Tot. (n=34)	1(2.9)	1(2.9)	3(8.8)	3(11.8)	12(35.3)	13(38.2)	4.88	1.25
Physics	Yes (n=18)	0(0.0)	0(0.0)	0(0.0)	4(22.2)	4(22.2	10(55.6)	5.33	.082
	No (n=16)	0(0.0)	2(12.5)	1(6.3)	3(18.8)	6(37.5)	4(25.0)	4.56	1.27
	Tot. (n=34)	0(0.0)	2(5.9)	1(2.9)	7(20.6)	10(29.4)	14(41.2)	4.97	1.12
Electrical Sciences	Yes (n=18)	0(0.0)	0(0.0)	1(5.56)	4(22.2)	6(33.3)	7(38.4)	5.06	0.91
	No (n=16)	1(6.3)	2(12.5)	0(0.0)	5(31.3)	4(25.0)	4(25.0)	4.31	1.49
	Tot. (n=34)	1(2.9)	2(5.9)	1(2.9)	9(20.6)	10(29.4)	11(41.2)	4.71	1.27

Note. Likert Scale = Disagree Strongly (1), Disagree Moderately (2), Disagree Slightly (3), Agree Slightly (4), Agree Moderately (5), Agree Strongly (6).

Table 6 continued: *Perceptions of Nuclear Uniform Curriculum Program (NUCP) Core Fundamentals Preparedness*

Question 3	Employed Y or N	Disagree Strongly n (%)	Disagree Moderately n (%)	Disagree Slightly n (%)	Agree Slightly n (%)	Agree Moderately n(%)	Agree Strongly n (%)	Mean	SD
Overall, program prepared me to meet these Nuclear Uniform Curriculum Program (NUCP) core fundamentals:									
Basic Atomic and Nuclear Physics	Yes (n=18)	0(0.0)	0(0.0)	0(0.0)	3(16.7)	3(16.7)	12(66.7)	5.50	.076
	No (n=16)	1(6.3)	0(0.0)	1(6.3)	2(12.5)	6(37.5)	6(37.5)	4.88	1.32
	Tot. (n=34)	1(2.9)	0(0.0)	1(2.9)	5(14.7)	9(29.4)	18(51.5)	5.21	1.11
Heat Transfer and Fluid Flow	Yes (n=18)	1(5.6)	0(0.0)	0(0.0)	4(22.2)	6(33.3)	7(38.4)	4.94	1.23
	No (n=16)	2(12.5)	0(0.0)	0(0.0)	3(18.8)	7(43.8)	4(25.0)	4.56	1.50
	Tot. (n=34)	3(8.8)	0(0.0)	0(0.0)	7(20.6)	13(38.2)	11(32.4)	4.76	1.37
Chemistry	Yes (n=18)	0(0.0)	0(0.0)	0(0.0)	5(27.8)	4(22.2)	9(50.0)	5.22	0.85
	No (n=16)	3(18.8)	1(6.3)	2(12.5)	2(6.3)	6(37.5)	2(12.5)	3.81	1.70
	Tot. (n=34)	3(8.8)	1(2.9)	2(5.9)	7(20.6)	10(29.4)	11(32.4)	4.56	1.50
Properties of Reactor Plant Materials	Yes (n=18)	0(0.0)	0(0.0)	0(0.0)	2(11.1)	2(11.1)	14(77.9)	5.67	0.67
	No (n=16)	0(0.0)	1(6.3)	0(0.0)	2(12.5)	5(31.3)	8(50.0)	5.19	1.07
	Tot. (n=34)	0(0.0)	1(2.9)	0(0.0)	4(11.8)	7(20.6)	22(64.7)	5.44	0.91
Radiation Detection and Protection	Yes (n=18)	0(0.0)	0(0.0)	2(11.1)	4(22.2)	2(11.1)	10(55.6)	5.11	1.10
	No (n=16)	1(6.3)	0(0.0)	0(0.0)	3(18.8)	5(31.3)	7(43.8)	5.00	1.27
	Tot. (n=34)	1(2.9)	0(0.0)	2(5.9)	7(20.6)	7(20.6)	17(50.0)	5.06	1.19
Reactor Plant Protection and Safety	Yes (n=18)	0(0.0)	1(5.6)	0(0.0)	3(16.7)	3(16.7)	11(61.1)	5.28	1.10
	No (n=16)	0(0.0)	1(6.3)	1(6.3)	0(0.0)	5(31.3)	9(56.3)	5.25	1.15
	Tot. (n=34)	0(0.0)	2(5.9)	1(2.9)	3(8.8)	8(23.5)	20(58.8)	5.26	1.12
Computers (plant specific)	Yes (n=18)	0(0.0)	0(0.0)	3(16.7)	6(33.3)	5(27.8)	4(22.2)	4.56	1.01
	No (n=16)	1(6.3)	3(18.8)	2(12.5)	3(18.8)	4(25.0)	3(18.8)	3.94	1.56
	Tot. (n=34)	1(2.9)	3(8.8)	5(14.7)	9(26.5)	9(26.5)	7(24.2)	4.26	1.34
Basic Systems Knowledge	Yes (n=18)	0(0.0)	1(5.6)	0(0.0)	1(5,6)	4(22.2)	12(66.7)	5.44	1.01
	No (n=16)	0(0.0)	0(0.0)	0(0.0)	2(2.9)	9(56.5)	5(31.3)	5.19	0.63
	Tot. (n=34)	0(0.0)	1(2.9)	0(0.0)	3(8.8)	13(38.2)	17(50.0)	5.32	.087
Basic Components Knowledge	Yes (n=18)	0(0.0)	0(0.0)	2(11.1)	1(5.6)	4(22.2)	11(61.1)	5.33	1.00
	No (n=16)	0(0.0)	0(0.0)	0(0.0)	2(12.5)	8(50.0)	6(37.5)	5.25	.066
	Tot. (n=34)	0(0.0)	0(0.0)	2(5.9)	3(8.8)	12(35.3)	17(47.1)	5.29	.086

Note. Likert Scale = Disagree Strongly (1), Disagree Moderately (2), Disagree Slightly (3), Agree Slightly (4), Agree Moderately (5), Agree Strongly (6).

Table 7:

Question	Mean	SD
Teaching methods, procedures, and course content program were:		
A. very pertinent to my major.	4.32	0.79
B. very current and meaningful to me.	4.18	0.95
Related and support courses were:		
A. very pertinent to my major.	4.74	1.01
B. very current and meaningful to me.	4.65	1.16
The work experience aspect of the program was:		
A. readily available at convenient locations.	4.18	1.84
B. readily available at convenient times of day.	4.18	1.75
Career planning information provided by college:		
A. successfully met my needs and interests.	3.76	1.71
B. successfully helped me plan my program.	4.00	1.71
Job success information on former graduates:		
A. successfully helped me make career decisions.	3.31	1.63
B. clearly conveyed job opportunities available via this occupation.	3.58	1.60
Placement services at college:		
A. successfully helped me find employment opportunities.	3.26	1.87
B. prepared me well to apply for a job.	3.62	1.68
Occupational instructors:		
A. knew the subject matter and occupational requirements well.	5.65	1.59
B. were always available to provide help when I needed it.	5.21	1.93
Instructional support services (such as tutoring, lab assistance) :		
A. always available to meet my needs and interests.	4.26	1.24
B. always provided by knowledgeable interested staff	4.41	1.35
Instructional lecture and laboratory facilities:		
A. always provided adequate lighting, ventilation, heating, power and other utilities.	5.55	0.74
B. always included enough work stations for # of students enrolled.	5.39	1.01
Instructional equipment:		
A. always current and representative of the industry.	5.06	1.10
B. always in sufficient quantity to avoid long delays in use.	5.06	1.07
Instructional materials (e.g., textbooks, reference books, supplies):		
A. always available and conveniently located for use as needed.	5.09	1.04
B. always current and meaningful to the subject.	4.97	1.29

"computers (plant specific)." Chemistry, item 16F, was the only topic in this area that stood out as substantially different between those employed in the energy field and those who were not, with a mean difference of 1.41 points.

Other questions on the survey asked about various components of the program, such as the instructors, facilities, and career services; these are summarized in Table 7. Some of the highest ranked items were instructors' knowledge of subject matter and instructional facilities; some of the lowest ranked items were job information and employment services.

DISCUSSION

This study investigated the concerns, ideas, and recommendations for understanding current practices or sustaining those that best meet the needs of the stakeholders regarding development and implementation of the Energy Production Technology program. It was essential to assess the feedback process within this partnership to determine if the program was yielding effective results as perceived by program graduates and their employers. Equally important was to determine the role played by the advisory committee that was developed to implement and provide oversight to the program.

What the findings of this study brought to light was that, through the guidance of the advisory committee, the college developed a program supported by the NUCP and the outcome was qualified graduates. Also evident was that the feedback loop generally worked well, but there were times when it did not always happen and issues went unresolved. For example, feedback was seldom provided by the plants to determine how the program graduates were performing on the job. Based on this, a key update to the conceptual framework would be to develop checks and balances to the feedback process by incorporating more intentional opportunities for feedback, such as holding monthly outreach sessions with employers. It is unfortunate that, although the graduates were qualified, there were not enough positions available at the plants for all who were eligible.

To summarize research question one, the program was successful for creating a qualified workforce. The interviews for the study also served as a reflection and summary of the key events for the advisory committee during the program development. The following important points that surfaced during the actual study: making sure the college has the right stakeholders; making sure that the students are better prepared for the nuclear culture, which includes the entrance exams and an understanding of the market necessary for a right-sized student population. A key addition to the literature would be research how the findings in this study corroborate with key principles from experts (like the importance of nuclear culture, stakeholders and labor demand) in the OECD and MPR reports cited.

The second research question sought information from individuals who have employed graduates from the college's energy program regarding their perceptions about how the college program prepared students for employment in the energy field. Employers were also asked to complete a skills' checklist on the graduates they hired. The power plant employers believed that EPT graduates were adequately prepared for employment, although they felt that the military recruits were better prepared based on the culture in which they work. This was viewed as a shortcoming for graduates at the onset of their employment, but employers stated that EPT graduates did catch up with their military colleagues as they spent more time in the nuclear culture. The contrast between the two groups was not anticipated by the advisory committee but was obvious to the employers when asked.

To summarize research question three, from the viewpoint of the program's graduates, the students felt they were adequately prepared for employment. However it should be noted that the study uncovered opinions that varied on several topics based on whether or not the students were employed in the energy industry. For example, almost 90% of those employed in the energy field believed they were well prepared compared to 56% of those not employed in the industry. The largest amount of feedback in the additional comments was undoubtedly the frustration some students felt regarding the lack of employment opportunities. Several students made comments regarding the inability to get a job at the local plants because they neither had a family member who worked at the plant who could possibly help them get a job or they did not have previous time in the Navy. In terms of adding to the research, surveying the graduates fills a present gap in the body of literature, because this is the first known NUCP program evaluation that collected data from all major stakeholder groups.

Several recommendations for further research have surfaced as a result of this study. First, it could be valuable to replicate the program evaluation to include participants at multiple power plants across the country, which would allow for comparison data to be used by the nuclear oversight committees enabling them to gage the perceptions of programming currently provided by community colleges. The second recommendation is to replicate the study to include all students that have taken courses in the energy program that have attained a position in the energy field; because only program graduates were surveyed in this study, some data opportunities were missed that would have increased the sample size substantially. The final recommendation is to evaluate the success of mock entrance exams. There is not presently any research that evaluates how studying with a practice test helps students be successful on passing the entrance examination tests at the power plants. It may be effective to include this process in the curriculum and implement it at other community colleges, and such a test would likely increase the students' pass rate.

This study affects policy and practice in career and technical education (CTE) by continuing to support the current practice of linking CTE education to a third-party certified curriculum. In order to receive Perkins grant funds, the Carl D. Perkins Career and Technical Education Act of 2006 requires that CTE programs are aligned, if possible, with third-party assessments, in this case the NUCP standards. The study also demonstrated that expectations from an advisory committee are important to an occupational program, and also speaks to how prospective programs should have both a thorough needs analysis and periodic program evaluations, including a survey of graduates. A final lesson learned is that developing a new technical program involves much more than simply having the right technology.

CONCLUSION

This study was initiated to find out how the EPT program at one Midwest community college successfully prepared graduates for a career in the energy industry.

From the viewpoint of the business and industry advisory committee created to oversee the Energy Production Technology degree program:

- The program was successful for creating a qualified workforce
- It is necessary to understand the job market and the culture, and it is important to retain the key players involved for decision making.

From the viewpoint of the power plant employer:

- Program graduates were adequately prepared for employment.
- There was a need to continually provide field experience and job shadowing opportunities to help students strengthen their awareness in the nuclear field.
- There was a need to create a stronger feedback loop within the program oversight process to help both the college and plant to continue a robust relationship.

From the viewpoint of the program's graduates:

- Students felt they were adequately prepared for employment.
- It is important to balance the job supply with the demand.

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Applying the Congruence Principle of Bloom's Taxonomy to Develop an Integrated STEM Experience through Engineering Design

By Paul A. Asunda and Sharita Ware

ABSTRACT

The concepts of interdisciplinary integration are interconnected beyond a theme, such that they cut across subject areas and focus on interdisciplinary content and skills, rather than subject-based content and skill (Drake, 1991; 1998; Jacobs, 1989). However, in today's learning environments, learning outcomes that teachers anticipate from their students and instruction are tied to educational standards. According to the principle of congruence in instructional design, in any situation, learning goals, anticipated outcomes, instructional strategies, and assessment methods should be carefully matched when designing a learning episode. To this end, this article presents a thought process by which the engineering and technology, science, and math teachers may reflect upon when preparing an integrated STEM course utilizing an engineering design process and the congruence principle of Bloom's taxonomy.

Key Words: STEM, STEM integration, congruence principle, Bloom's taxonomy, engineering design, assessment

INTRODUCTION

Our ever-changing, increasingly global society has brought forth challenges that are interdisciplinary, and many require the integration of multiple disciplines, specifically STEM concepts to solve them (National Academies, 2006). Integrated STEM has been seen as a vehicle to meet this objective. Ideas behind integration of interdisciplinary courses are intersected beyond a given goal, emphasizing connections between subject areas and focusing on interdisciplinary content and skills, rather than subject-based content and skills (Drake, 1991; 1998; Jacobs, 1989). It has been perceived that STEM disciplines offer a rich amalgamation of experiences that provide contextual cross-cutting concepts embedded in technological problem- based activities that can be realized through engineering design. The teaching of STEM integration should not only focus on content knowledge but also should include problem-solving skills and inquiry-based instruction (Wang, Moore, Roehrig, & Park, 2011). However, Honey, Pearson, and Schweingruber (2014) posited that designers of integrated STEM education initiatives must be explicit about the goals they aim to achieve and design the integrated STEM experience purposefully to achieve these goals. They also need to better articulate their intentions about why and how a particular integrated STEM experience will lead to particular outcomes and how those outcomes should be measured.

In the field now called engineering and technology, the educational message has been "technological literacy for all," clearly advocating a general educational philosophy. Hill (2006) posited that in the absence of an extant high school subject area to develop proficiency in engineering design, technology education courses naturally offered a continuum of experiences that emphasized engineering design principles. These experiences require that students identify probable solutions to problems designed in a context, as they experiment with simulated resources that mirror everyday technological systems. Such systems may include mechanical, structural, fluid, electrical, electronics, optical, thermal, biological, and materials technologies. Through the combination of these technologies, students follow the same procedures used by engineering teams in solving real-world problems as they develop products, processes, or systems that support human enterprises and institutions (Smith & Gray, 2009).

Custer (2000) noted a unique opportunity for the field through curriculum integration; he posited that "if the technology education profession is successful with an integration agenda, we could well find ourselves at the core of education in the 21st century. But integrated learning environments will be very different, the risks and demands will be considerable" (p. 130). It follows that the infusion of engineering design into technology education through problem-solving activities that culminate into projects, offers students opportunities to develop critical thinking skills, technical, and STEM literacy knowledge, and helps them to learn innovative practices. For these reasons, integrative STEM education, which promotes learning through connections among science, mathematics, technology education, and other general education subjects, is wholly consistent with the ideology of the profession. *This article presents a thought process by which the congruence principle of Bloom's taxonomy may guide the engineering and technology, science and math teachers as they design and develop an integrated STEM course utilizing an engineering design process as the basis.*

The Standards, Backward Design, and Developing Congruent Integrated STEM

In today's learning environments, outcomes that teachers anticipate from their students and instruction are tied to educational standards. Proponents of standard-based educational reforms claim that standards offer teachers a congruent process in designing their instructional practice. By specifying what knowledge or skills students must demonstrate, standards point toward the instructional practices that teachers could employ (Cohen, 1996; Darling-Hammond, 2004; Rowan, 1996).

According to the principle of congruence in instructional design, in any situation, learning goals and outcomes, instructional strategies, and assessment methods should be carefully aligned (Chyung & Stepich, 2003; Gagne, Wager, Golas & Keller, 2005; Dick, Carey, & Carey, 2008). To achieve congruence, instructional design models suggest identifying intended learning outcomes that mirror objectives of a course and determining the types of learning activities that represent these objectives. Wiggins and McTighe (2005) capture the principle of congruence through the backward design process, a three-stage process that teachers can use to develop integrated STEM courses. More specifically, to start this process, teachers begin by asking themselves: What is worthy and requiring of understanding? To answer this question, one must consider local, state, and national standards. If the answer from this first question is not based on the standards, it is probably not worthy of teaching and learning (Reeve, 2002; Wiggins & McTighe, 2005).

Standards are the driving force behind today's education and they should be addressed in lesson design. Teachers of engineering and technology education have subscribed to Standards for Technological Literacy (STL) as a vehicle to integrate engineering design principles and concepts into the curriculum. The ITEEA board of directors (2009) stated that the content contained within the STL standards was the basis for students to develop 21st Century STEM- related knowledge —the very core of abilities needed for students to become advanced problem solvers, innovators, technologists, engineers, and knowledgeable citizens. Additionally, recent standards being integrated into the curriculum like the Common Core State Standards (CCSS) and the Next Generation Science Standards (NGSS) seek to focus teachers on helping students make connections across the disciplines (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; NGSS, 2013). The underlying principles that inform both sets of standards are active engagement of students in authentic tasks, support for development of conceptual knowledge and reasoning, and application of knowledge in real-world contexts (Honey et al., 2014). Hence, standards present the content (knowledge and abilities) that teachers should utilize to develop contextual authentic tasks that support the development of conceptual knowledge and critical thinking leading to STEM literacy. It can then be argued that, for teachers to develop congruent integrated STEM courses, the backward design process helps students understand connections made between subject areas and internalize cross-cutting concepts rather than memorize them. In this way, learning outcomes and objectives serve as a cornerstone for the development of an integrated STEM course, helping to determine the instructional strategies and assessment methods that will be used which, in turn, helps to ensure the congruence of the instruction (Chyung & Stepich, 2003).

Instructional Practices that May Reflect Integrated STEM in the Curriculum

Furner and Kumar (2007) noted that, "an integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners" (p. 186). Integrated STEM has been viewed as an approach to teaching and learning in a manner such that the curriculum and content of the four individual STEM disciplines seamlessly merge into real-world experiences contextually consistent with authentic problems and applications in STEM careers. Such integration may refer to making meaningful connections between core disciplinary practices of each STEM domain being integrated, with the goal of using this integrated knowledge to solve real-world problems (Mobley, 2015). The integration of STEM concepts can then be visualized as follows, consider (see Figure 1) the content of units in Sciences, Mathematics and Engineering/ technology education. Due to the overlap of concepts identified in these units, they may be considered for integration through a problem-based learning activity that culminates into a project enabling students to operationalize STEM concepts. In addition, the content and assessment type identified in the area that these disciplines intersect need to be clearly specified to assess learning outcomes. A second approach (see Figure 2) can be viewed as follows; units from the Sciences and Engineering/technology Education have been integrated. A unit from Mathematics is integrated with a unit from Engineering/ technology Education. Dugger (2010) noted that there are a number of ways that STEM can be taught in schools today. One way is to integrate one of the STEM disciplines into the other three (e.g., integrating engineering aspects into science, technology and mathematics). And a more comprehensive way is to infuse all four disciplines into each other and teach them as an integrated subject matter. In this regard, Erekson and Shumway (2006) noted that a full interdisciplinary model, in which the content from two or more disciplines are merged, has the potential to be very effective in technology education. Although this model appears to show promise, it also appears the most elusive. Thus, achieving congruence in designing learning experiences that simulate an integrated STEM course has revealed the challenges of making connections across the STEM subjects. Honey et al. (2014) suggested that instructors should build in their teaching *opportunities that make STEM connections explicit to students and educators (e.g., through appropriate scaffolding and sufficient opportunities to engage in activities that address connected ideas).*

BASIS FOR CONGRUENCE PRINCIPLE

Bloom's Taxonomy and the New Revised Bloom's Taxonomy

Bloom's Taxonomy is a hierarchical way of classifying thinking according to six cognitive levels of complexity. The lowest three levels include the following: **knowledge**, **comprehension**, and **application**. The highest three levels include: **analysis**, **synthesis**, and **evaluation** (Bloom & Krathwohl, 1956). Throughout the years teachers have encouraged their students to think through these cognitive levels and to operate at the higher levels when solving problems. For example, it has been perceived that a student functioning at the "application" level also has mastered the material at the "knowledge" and "comprehension" levels. To this end, the taxonomy is used as a framework for categorizing and classifying learning objectives according to the skill level required to meet desired learning outcomes. Outcomes describe what students are expected to know and be able to do by the end of a given instructional period. These outcomes relate to skills, knowledge, and behaviors that students attain as they progress through a given learning experience. Anderson and Krathwohl (2001) modified Bloom's taxonomy by adding another dimension of knowledge types: factual, conceptual, procedural,
and meta-cognitive. Factual knowledge can best be defined as the basic elements that all students must acquire within a discipline, whereas

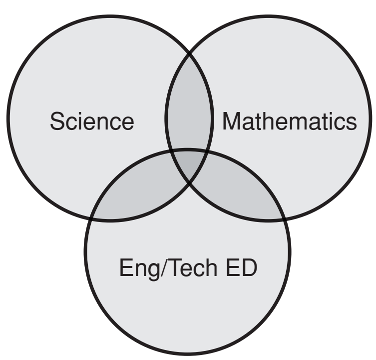

Figure 1. Integration of content units in Sciences, Mathematics, and engineering/ technology education.

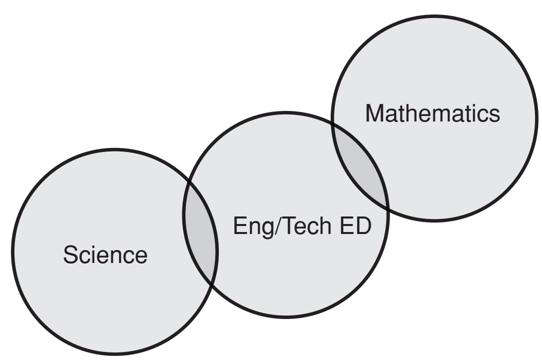

Figure 2. Integration of content units in Sciences, Mathematics, through engineering/technology education.

conceptual knowledge can best be defined as the understanding of inter-relationships among the basics of a discipline to the larger overall structure and explain how they function together. Procedural knowledge requires that students know how to conduct inquiry, understand and apply techniques and methods using appropriate procedures, and metacognitive dimensions require that students are aware of their own knowledge level, including the knowledge and use of heuristics. Anderson and Krathwohl renamed the earlier hierarchy of levels from nouns to verbs. A brief summary of the adaption and extension of Anderson and Krathwohl's (2001) revised Bloom's taxonomy follows:

1. Remember: recognizing, recalling (repeating verbatim): state [for example, the steps in the procedure for changing a flat tire].
2. Understand: interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining (demonstrating understanding of terms and concepts): explain [in your own words the concept of design].
3. Apply: executing, implementing (applying learned information to solve a problem): calculate [how much materials one may require to complete a given construction project].
4. Analyze: differentiating, organizing, attributing, checking, critiquing using existing criteria (breaking things down into their elements, formulating theoretical explanations or mathematical or logical models for observed phenomena): explain [why mass might affect the velocity of a given object].
5. Evaluate: (a) "Critiquing" based on self-designed/chosen criteria, (b) "Deciding" in the light of larger context, human values and ethics, (making and justifying value judgments or selections from among alternatives): select [from among available options for expanding production capacity, and justify your choice].
6. Create: generate, plan, and produce (creating something, combining elements in novel ways): make up [a homework problem involving material covered in class this week].

Bloom & Krathwohl, (1956) indicated that ideally researchers in each major field would use this taxonomy to develop their own unique objectives and language. They suggested that a discipline-specific taxonomy could offer assessment with greater details, with influences from experts in their respective fields, and break down the categories into subcategories and levels of education with new groupings and combinations.

The Accreditation Board for Engineering and Technology (ABET) evaluates every engineering-related program (departments and interdisciplinary course programs) in the United States and determines whether they meet certain standards (ABET, 2013). According to Felder and Brent (2004), this body determines whether the said programs and courses meet ABET- defined criteria and benchmarks that lead to realization of identified standards. Prior to a review of a program, instructors seek to evaluate the appropriateness of the educational objectives, the extent to which the specified outcomes result in the objectives, and whether they incorporate specific attributes specified by ABET. For engineering and technology education programs these would be ABET (Outcomes 3a–3k).

As STEM initiatives become the driving force of educational change through K-16, Clark and Ernest (2010) argued that all instructors would say that they want their students to master higher level thinking skills as reflected by the revised Bloom's taxonomy. To this end, the design of integrated STEM activities should focus on the extent to which the course's learning objectives map onto the outcomes, the feasibility of the specified outcome assessment and continuous improvement processes, and the seriousness with which the program is implementing those processes. Chyung and Stepich (2003) suggested that Bloom's taxonomy of educational objectives was instrumental in making sure there was congruence among the planning, instruction, and assessment process of design learning experiences.

ROLE OF ENGINEERING DESIGN IN ENGINEERING AND TECHNOLOGY EDUCATION

Researchers, (Ereckson & Custer, 2008; Pinelli & Haynie, 2010; Wicklein, 2004) advocated for engineering as the focus for technology education because engineering provides a solid framework to design and organize curriculum, while providing an ideal platform for integrating mathematics, science, and technology. According to Atman et al. (1999) design is a central element of engineering, and all engineers perform some type of design function. Likewise, Warner and Morford, (2004) stated that design is fundamental to the study of technology, and design cannot be fully appreciated without an understanding of technology. This statement implies that, if technology is to be fully understood, then the concepts of design must be comprehended. The Standards for Technological Literacy (ITEA, 2000/2002/2007) Standards 8, 9, 10, and 11 highlight design concepts to be introduced throughout the K-12 curriculum. Hailey et al. (2005) posited that the design process described in Standard 8 for students in Grades 9-12 is very similar to the introductory engineering design process described in freshman engineering design textbooks, specifically the book by Eide, Jenison, Mashaw, and Northrup (2002). Hailey et al. (2005) noted two exceptions as highlighted in Figure 3, and Mosborg, Adams, Kim, Atman, Turns, and Cardella (2005) affirmed that the number of stages in these diagrams ranged from a few to several dozen, depending on the detail and complexity with which the design process is rendered.

Today, the field is witnessing exponential growth of engineering practices, STEM- related curriculums (e.g., Project Lead the Way, STEM Academy, CISCO investment in STEM, and Microsoft Math Partnership) are being introduced

Classical Engineeringy Design process
(from introductory engineering text by Eide, et al.)

- IDENTIFY THE NEED
- DEFINE THE PROBLEM
- SEARCH FOR INFORMATION
- IDENTIFY CONSTRAINTS
- SPECIFY EVALUATION CRITERIA
- GENERATE ALTERNATIVE SOLUTIONS

Engineering Analysis
Optimization Decision

Design specifications
(So it can be made)

Communications

Classical Engineeringy Design process
(from introductory engineering text by Eide, et al.)

- DEFINING A PROBLEM
- BRAINSTORMING
- RESEARCHING AND GENERATING IDEAS
- IDENTIFYING CRITERIA AND SPECIFYING CONSTRAINTS
- EXPLORING POSSIBILITIES

Selecting an approach
and developing a design making
a model of prototype. Testing and
evaluating the design specifications
Refining the design

Communicating process and results

Creating or making it

Figure 3. Engineering design process compared to technology education design process

at the K-12 curriculum level. Additionally, the federal government in financial years 2009, 2010, and 2011 offered approximately $867 million to support activities related to STEM education and increased outreach activities that support STEM initiatives through organizations like the National Aeronautics and Space Administration (NASA), The National Science Foundation programs (President's Council of Advisors on Science and Technology, 2010).

These new initiatives and curricula imply that educators should design collaboration strategies and new instructional practices. As suggested by Chyung and Stepich (2003) Bloom's taxonomy still has merit as a guide for instructional planning for two specific reasons. First, it reminds educators that the key to effective instruction is the congruence or "degree of correspondence among the objectives, instruction, and assessment" (Anderson & Krathwohl, 2001, p. 10). Second, because it is analytical, it helps remind instructors that learning is made up of a complex array of cognitive skills. At the same time, it doesn't prevent them from designing instruction in a more dynamic way, in which a low-level cognitive skill can be learned in conjunction with a high-level cognitive skill. To this end, the integration of engineering design into technology education continues to provide the field with authentic learning experiences that are ideal education required to help nations to prosper in the technologically interdependent world in which we live. Responsibility for this falls on the engineering and technology education teacher working in collaboration with colleagues in science and math.

USING BLOOM'S TAXONOMY TO DEVELOP A CONGRUENT INTEGRATED STEM LESSON THROUGH ENGINEERING DESIGN

Haag, Froyd, Coleman, and Caso (2005) stated that data can only be collected on observable behaviors and ABET student outcomes do not define observable behaviors; therefore, learning objectives should be formulated for each outcome describing the desired observable student performance. This may imply that an engineering technology education teacher seeking to integrate STEM concepts into their curriculum may redesign traditional technology education problem-based activities into a STEM-integrated project that depicts a stated standard performance and desired outcome. Such projects may include (e.g., Cookie Package Design Challenge; Sustainable House Project, and more) that can be repurposed to deliberately help students realize how the STEM concepts being taught overlap in a given learning activity and how these lead to both the solving of a given design problem and the realization of a complete project product.

For the purposes of this article the authors utilized an air blaster car. The main focus of the design of this car revolves around four main areas: principles of aerodynamics involved with air blaster car construction, design of vehicle, construction of vehicle, and racing of vehicle. Such a lesson can be best illustrated as described by Figure 2 where scientific concepts that explain the principles of aerodynamics, and the mathematic principles behind racing the car (i.e., calculating speed based on the time the car will cover a given length, integrated with engineering technology principles behind design and construction of the vehicle). Given this activity, Wiggins and McTighe (2005) advocated for the backward design process, which prompts instructors to ask, how best do we go about designing the car, and what kind of lessons and practices are needed to master key performances? This approach also requires that educators operationalize the identified standards in terms of assessment evidence as they begin to plan a unit. Instructors are tasked with asking themselves, what they would accept as evidence that the students have attained the desired understandings and proficiencies.

The next steps will be to develop objectives, learning activities and materials, and evaluation of criteria for each of the four areas. At this point the congruence principle becomes particularly important. Maintaining the congruence among the objectives, learning activities, and evaluation criteria is critical to the effectiveness of the instruction. Congruent instruction means that learning activities are designed to support the objectives and that the evaluation methods are designed to assess important learning outcomes represented by the objectives. A curriculum mapping exercise would provide a snapshot of where educators stand in light of the anticipated learning outcomes that students will be able to demonstrate. Bloom's taxonomy of educational objectives is instrumental in making sure that there is congruence among the components of each module.

Bloom's original taxonomy was used to determine the levels of the objectives for each module and to design learning activities through which students would accomplish those objectives. Prior to developing learning activities, the authors determined the levels in the taxonomy for each objective. Because the learning sequence and processes are interdependent, it was listed as the highest level from the taxonomy, in conjunction with lower, supporting levels. These are summarized in Table 1.

Table 1: *Standards, Levels of Objectives, and Knowledge Dimension*

STL/NGSS Standards	Objectives	Levels in RBT	Knowledge dimension in RBT
STL8-10-MS NGSS-MS-PS3-1.	Research pertinent information on underlying principles of aerodynamics with air blaster car construction	Remember and Understand	Factual
STL9, 16-MS, MS-PS3-3., MS-PS3-4.	Recognize principles of Newton's Third Law of Motion and how it relates to air blaster car competition	Understand and Apply	Conceptual
STL9, 16-MS MS-PS3-2.	Explain how mass, friction, and design of air blast car relate to its movement	Understand and Apply	Procedural
STL9-11-MS MS-PS3-4., MS-PS3-5.	Utilize the process of engineering design to design and develop a drawing design which shows understanding of air blaster concepts and construct a prototype car, present the model to peers	Apply, Analyze, Create and Evaluate	Meta-cognitive

DEVELOPING LEARNING ACTIVITIES FOR THE REMEMBER AND UNDERSTAND LEVEL (FACTUAL) DIMENSION

Research: Students were asked to conduct research into underlying principles of winning car designs. This could entail students' finding information about the basics of aerodynamics as it relates to cars and, specifically, the underlying principles into construction of these cars. Students may be asked to informally demonstrate their knowledge and comprehension of factual knowledge into the design of at least three different designs based on the aerodynamic design of the cars.

Students were expected to recall the underlying principles of aerodynamics in car design using terms that they elicited from the research activity and elaborate on them using more common terms to illustrate aerodynamic designs (e.g., shape, sleek outline, sometimes relating to with examples to show comprehension of the concepts). The teacher should give students opportunities where they can connect the factual to conceptual knowledge as they progress through the activity. This connection should help students construct and deconstruct knowledge as they understand and apply principles of Newton's Third Law of Motion and how it relates to air blaster cars through small group discussions. Through this process students may demonstrate the intended level of learning (comprehension) and then go beyond that to demonstrate an unanticipated higher level of learning (e.g., application, analysis, synthesis, or evaluation) by connecting factual to conceptual knowledge.

LEARNING ACTIVITIES FOR THE APPLICATION AND ANALYSIS LEVELS (PROCEDURAL) DIMENSION

Based on discussions that ensue, the teacher should design classroom experiences that give students an opportunity to explore and explain how force, mass, friction, and design parameters relate to an air blaster car. By explaining and demonstrating the application of force on an object causes an acceleration of that object, that is, the more force you have, the faster an object goes, and helping students comprehend that force is not the only factor in the movement, or acceleration of an object. Other factors such as the friction, air or fluid resistance, and pressure may affect the acceleration as well. The students may be asked the following questions: Why is it important to be aware of how force and mass affect acceleration? What other factors may play a role? Why? How? Students eventually will be expected to apply these principles to the design of a car, Figure 4. Students can provide feedback to sketches of prototype cars for each other, and the can also provide examples of where they have seen these principles used. This method helped students consider different views of the same situation, promoting application and analysis.

Rules:
1. Design MUST touch all sides of the rectangle layout
2. Design MUST clear all predesign holes and cut outs
3. Design MUST have a color scheme (using color pencils)

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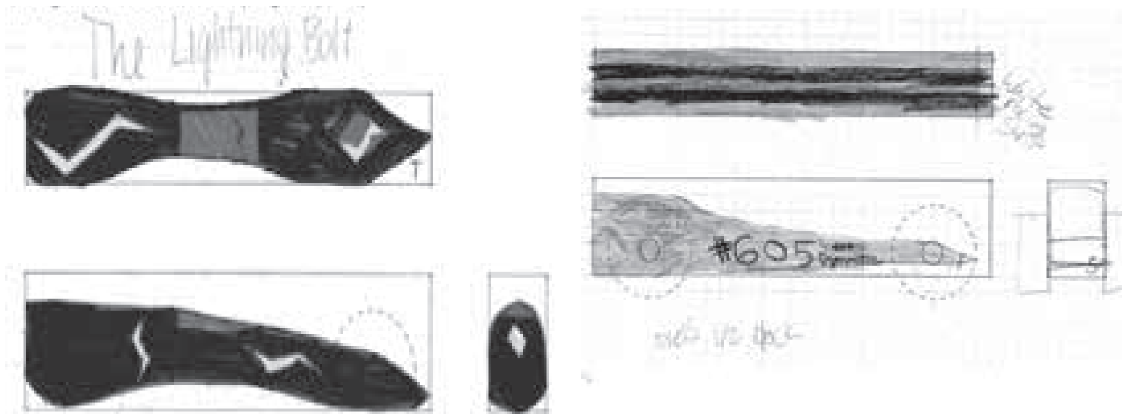

Figure 4. Students' sketches depicting factual and conceptual levels of Bloom's taxonomy

Figure 5. Students' prototypes depicting conceptual and procedural levels of Bloom's taxonomy

Figure 6. Students' prototypes depicting procedural and meta-cognitive levels of Bloom's taxonomy

Table 2: *Suggested Evaluation Procedure for Air Blaster Car Project to Integrate STEM concepts*

STL/NGSS Standards	RBT Dimension	Activity corresponding to Original bloom cognitive processes	Suggested Evaluation
STL8-10-MS NGSS-MS-PS3-1.	Factual	Students to submit portfolio of sketches that document initial research of challenge, criteria and constraints they experienced used to design air blaster car, Car Design Sketches.	Complete submitted portfolios with at least 2 sketches, detailing the challenge, criteria, and constraints in the context of performance improvement.
STL9, 16-MS, MS-PS3-3., MS-PS3-4.	Conceptual	Speed and weight of car: students to record weight of their cars in grams, race car three times on a race track and calculate the speeds of their cars by utilizing the formula Speed = Distance / Time. Compare the data from their findings to those of their peers, and be able to explain how the weight (mass) of their car impacted the rate of the speed it travelled.	Application of the Formula speed = distance/time upon students recording of weight of the car and tie to race on a specified length track. Students provide an explanation of how the mass of their car impacted the speed compared to at least 2 peers.
STL9-11-MS MS-PS3-2.	Procedural	Manufacture (cut, shape, sand, paint, and detail) car as per chosen design utilizing provided materials and tools. Weigh car and race car on track 3 times and record the speed	Application of the process of engineering design and STEM concepts to design and manufacture air blaster car.
STL9-11-MS MS-PS3-4., MS-PS3-5.	Meta-Cognitive	Project reflection, students to write about their overall experience with project. For example, how their compared to peers, and what would they change about their car to make it better, faster. More aerodynamic? Smaller wheels? Shorter race track?	Justification of their selection of given design, and how these design modeled the design process and STEM concepts compared to the design of 2 peers. A description of how they can improve their design or their peers utilizing the engineering design process.

They are required to keep a portfolio of sketches and drawings showing the development of the air blaster's final form. The design of this vehicle is not a linear process, and it is expected that many revisions of the design will occur. Thus, each student's car will have a different form that is based upon their design envelope (see Figure 5). Airblaster cars must be built to certain specifications to avoid interference with the propulsion system (i.e., placement of hole, wheels, launch system, guidance system, and the prevention of failure or destruction during testing). During the construction process, the students will learn to use tools, machines, and safety equipment, and they will identify potential safety hazards associated with them. Finally, the testing of the car will lead to both a self- evaluation as well as a peer evaluation process, as the vehicles are propelled down a track by compressed air (see Figure 6). The process of testing the cars will allow the students to compare and analyze the different designs for success and needed improvements. It is intended that a dialog between students will help further the design of the dragsters and improve results on the drag strip.

Evaluating Engineering Design Process Learning Outcomes Based on Bloom's Taxonomy

A backward design process as described by Wiggins and McTighe (2005) facilitates the design of an evaluation process. Each of the identified learning dimensions (i.e., outcomes, Bloom's taxonomy) guided the instructors in setting evaluation criteria that would be congruent with the learning objectives and standards. This evaluation maps the final products of a given task, to the learning objectives. Evaluating the design process regarding the degree to which the students have achieved identified learning outcomes with respect to integrating STEM concepts requires relevant, appropriate, and informative data upon which judgments can be based (Haag et al., 2005). A documented evaluation procedure (see Table 2) provides an approach to obtaining data relative to the process of engineering design in a technology education class project that may seek to integrate STEM concepts. Students could be provided the following guidelines for evaluations purposes.

CONCLUSION

The rich products of technology education provide a context for successful integration of STEM concepts into the K-12 curricula. However, designing instruction that offers meaningful experiences to meet the challenges of STEM integration in technology education is a difficult task for any educator. A conceptual framework offers educators a reference point to their instructional practices and standards and provides educators with a blueprint of expected learning outcomes. STL standards offer a starting point for designing learning activities while NGSS seek to help teachers identify cross-cutting concepts across STEM disciplines in the context of their teaching. Wiggins and McTighe (2005) have suggested backward design as a strategy to help students understand the connections between subject areas and internalize cross-cutting concepts. Chyung and Stepich (2003) emphasized that instructional components, such as instructional objectives, instructional activities, and assessment methods should be carefully matched to help students achieve the intended learning outcomes. In closing, this article presents a locus by which technology education instructors can incorporate STEM concepts into the K-12 curriculum.
As instructors incorporate a backward design process to teach STEM concepts in technology education courses, Bloom's taxonomy can be a helpful guide in achieving congruence in integrating both cross-cutting concepts and how a particular integrated STEM experience may capture and enhance concepts that can be applied to solve complex challenges; it also may lead to both a particular outcome and the way in wish this outcome may be evaluated.

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The 2014 Paul T. Hiser Exemplary Publication Award Recipients

Jeffrey M. Ulmer, Douglas Koch, and Troy Ollison

"Characteristics of Today's Applied Engineering College-Level Educator"

The Board of Editors of The Journal of Technology Studies and the Board of Directors are pleased to announce the recipient of the Paul T. Hiser Exemplary Publication Award for Volume XL, 2014.

The Board of Directors established this award for deserving scholars. In recognition for his exemplary service to the profession and to the honorary as a Trustee and Director, the award bears Dr. Hiser's name. It is given to the author or authors of articles judged to be the best of those published each year in this journal.

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Each member of the Editorial Board recommends the manuscript that he or she considers the best of those reviewed during the year. The board nominates articles based on their evaluation against specific criteria. A majority vote of the editors is required for the award to be made. The honor society's Board of Directors renders final approval of the process and the award.

Criteria

1. The subject matter of the manuscript must be clearly in the domain of one or more of the professions in technology.

2. The article should be exemplary in one or more of the following ways:
   - Ground-breaking philosophical thought.
   - Historical consequence in that it contains significant lessons for the present and the future.
   - Innovative research methodology and design.
   - Trends or issues that currently influence the field or are likely to affect it.
   - Unique yet probable solutions to current or future problems.

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GUIDELINES FOR

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The immense diversity of technology, along with its applications and import, requires that authors communicate clearly, concisely, and only semi-technically to readers from a diverse set of backgrounds. Authors may assume some technical background on the part of the reader but not in-depth knowledge of the particular technology that is the focus of the article. Highly technical articles on any field of technology are not within the purview of the journal. Articles whose focus has been extensively explored in prior issues of the Journal are of potential interest only if they (a) open up entirely new vistas on the topic, (b) provide significant new information or data that overturn or modify prior conceptions; or (c) engage substantially one or more previously published articles in a debate that is likely to interest and inform readers. Syntheses of developments within a given field of technology are welcome as are metanalyses of research regarding a particular technology, its applications, or the process of technical education and/or skill acquisition. Research studies should employ methodological procedures appropriate to the problem being addressed and must evince suitable design, execution, analysis, and conclusions. Surveys, for example, that exhibit any or all of the following characteristics are of no interest to the journal: (a) insufficient awareness of prior research on this topic, (b) insufficient sample size, (c) improper survey design, (d) inappropriate survey administration, (e) high mortality, (f) inadequate statistical analysis, and/or (g) conclusions not supported by either the data or the research design employed. The JOTS is neutral in regards to qualitative, quantitative, or mixed method approaches to research but insists on research of high quality.

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