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The Skills Gap in U.S. Manufacturing: The Effectiveness of Technical Education on the Incumbent Workforce

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THE SKILLS GAP IN U.S. MANUFACTURING:
THE EFFECTIVENESS OF TECHNICAL EDUCATION
ON THE INCUMBENT WORKFORCE

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This thesis explores the skill sets of the current American workforce, the skills required in modern, technically advanced U.S. manufacturing facilities, and the multiple approaches postsecondary education has employed to bridge the gap between the two. Millions of dollars are spent each year educating and training the incumbent workforce without any definitive measure of whether the financial investment or effort is actually providing a return.

To illustrate, organizations typically require a projected return-on-investment (ROI) before committing funds to a project. However, the same approach does not seem to be applied when investing in human capital for the purpose of improving the technical skills required of the incumbent workforce in manufacturing. Training efforts and effectiveness are typically measured by the amount of training dollars spent and some form of post-training satisfaction survey.

Adding to the dilemma is the fact that postsecondary education and workforce development organizations do not have performance metrics that align with manufacturing or industry metrics. The misalignment becomes more evident when trying to determine if the funding is actually paying off once an incumbent worker completes their training and returns to the shop floor. This project sought to determine if a return on training dollars could be quantified and measured so that industry can discern whether

training is value-added or if postsecondary training providers should better align their product with customers' expectations.

Experiments were conducted with incumbent production workers to determine if an educational intervention translated to a quantifiable return on an organization's training investment. Measurements in the time it took to repair a piece of production equipment were taken and compared to post-intervention times for the same activity to determine if hypothesized improvements actually occurred. Data was also collected and analyzed to determine if incumbent workers' prior maintenance experience had an impact on the reduction of time to repair the production equipment.

The experiment illustrated a statistically significant difference in the repair times for those who received the intervention. The second phase of the experiment that sought to determine if prior maintenance experience was beneficial to improving repair times did not support the hypothesized outcome.

Introduction

There is a perception shared among U.S. employers, economists, educators, and policy makers that a skills gap currently exists between the available workforce and vacant manufacturing job requirements. There are also differing positions as to which U.S. industries have been most impacted by the skills gap, who or what is responsible for the gap, and how to bridge the skills gap. Regardless, agreement can be found in the fact that a strong, engaged workforce is critical to a thriving economy, particularly one that is less than a decade into its recovery from a recession.

The skills gap has also become more prevalent as American manufacturers are attempting to re-establish their global market prominence by producing goods with highly automated, state-of-the-art production equipment and processes. U.S. manufacturers also share the notion the gap is widening despite improvements in economic growth and unemployment data in the wake of the Great Recession of 2008. Manufacturers have sought both traditional and innovative means to fill the vacancies, particularly those jobs requiring technical skills most often possessed by experienced industrial maintenance technicians.

There are several factors that have contributed to the decline in available skilled technicians: the surge in offshoring beginning in the early 1990s in order to capitalize on cheap labor in countries with emerging economies such as India and China; liberal trade agreements between the U.S. and emerging economies that fueled the offshoring movement; the Great Recession of 2008 that crippled a global economy; and a trade deficit between the U.S. and other countries valued at nearly $460 billion (Baily, Lawrence, Levy, & Sichel, 2004).

But there is evidence that suggests a reversing trend is underway as the laborers of the aforementioned emerging economies have become the newly formed middle class of their respective countries. As a result, there has been a demand for higher wages in order to support their improved lifestyles. The shift in expected wages has subsequently caused U.S. manufacturers with foreign interests to lose the comparative advantage that prompted their initial departure from U.S. soil. To that end, American producers of goods are now beginning to re-shore some of their products back to the U.S. At first glance, this would appear to be a sign of hope and resurrection to an all-but-dead industry and its workforce, but manufacturers are targeting advances in manufacturing technology (not manual labor) as the vehicle for increased output and growth. As such, reshoring has created even greater challenges for employers looking to fill vacancies in technically advanced positions.

The supporting cast of experienced, highly skilled maintenance technicians has been exiting the workforce in pursuit of retirement or other opportunities, and many employers are beginning to see a technical skills deficit emerge that is adversely impacting the productivity on their shop floors. According to the Skills Gap Institute's 2015 annual report, 600,000 skilled manufacturing positions in the U.S. are currently vacant, and a projected three and a half million of those same types of jobs will go unfilled over the next decade (McMenimin, 2015). Not only is the skills gap a threat to current manufacturing, but this deficit of talent could also potentially stifle the momentum of a re-shoring movement that has gained a foothold in the U.S. In 2013, re-shoring accounted for five percent of the increase in manufactured goods in America

(Deligio, 2014), but most of the products that were once made with manual labor are now produced
with sophisticated production equipment that requires a tech-savvy workforce to maintain and operate.

As manufacturing in the U.S. declined throughout the 1990s and mid-2000s, so did the number of high school graduates interested in careers related to manufacturing. The American Association of Community Colleges (AACC) reported that liberal arts and medically related associate degrees far outpaced those in manufacturing and technology during those same years, and the trend is continuing today (Juszkiewicz, 2016). Much like the coal industry of today, manufacturing has been increasingly seen as a dead-end, go-nowhere career option that only afforded jobs in dirty, dimly lit, and dangerous facilities. Combining the exodus of a qualified, technical workforce and an un-replenished pipeline of new talent only exacerbates the situation for domestic manufacturers.

While some workers have taken the initiative to improve their skill sets at their own expense, many employers are finding themselves burdened with the need to invest in their remaining workforce's technical education in an attempt to close the skills gap. Some companies have even begun training their production employees to fill the roles traditionally held by skilled maintenance technicians.

The United States Department of Labor developed the Trade Adjustment Assistance Community College and Career Training (TAACCCT) grant program with funding in excess of $1.9 billion to assist community colleges in addressing the technical needs of today's manufacturing workplace (USDOL, 2016). Additionally, the Advanced

Integrated Technology (AIT) program at Madisonville Community College (MCC) in Madisonville, Kentucky was established to not only provide educational pathways to individuals seeking a career as a multi-skilled maintenance technician, but also to provide education as a means to improve the technical skill sets of regional manufacturers' incumbent workforce. The online delivery of the AIT curricula is comprised of modularized, discipline-specific classes (i.e. electrical, hydraulic, programmable logic controllers, robotics, etc.) that allow employers the flexibility to choose only the classes that will address the specific needs of their employees. Students and incumbent workers can access technical content online and reinforce learned concepts through hands-on lab assignments conducted in the on-campus laboratory.

As a means of addressing the incumbent workforce skills gap, the AIT faculty can administer a pre-assessment (at the request of the employer) to determine which classes are needed to address specific deficiencies for each employee. Employees are given a pathway to completion that (theoretically) should improve their deficiencies.

Problem Statement

Organizations that invest in improving their employees' technical knowledge in order to keep pace with the growing skills demand should expect a reasonable, quantifiable return on their investment (ROI). The payback should theoretically be in the form of increased throughput of equipment with less downtime as a result of an improved technical workforce. However, little evidence suggests that educational opportunities afforded by the employer lead to an increase in productivity once the employee returns to the shop floor. In essence, the customer does not have definitive proof they are getting results from their investment. The most common measure of effectiveness for this type of educational intervention is the subjective perception of co-workers, supervisors, and/or the employee themselves.

Educational institutions have historically assessed their effectiveness with academic metrics such as student learning outcomes (SLO); the number of credentials awarded in a particular discipline; standardized exit exam scores; minority completion rates; and job placement statistics (Kotamraju, 2011). Additionally, little research has been conducted to determine if the education and retraining interventions are actually translating to improvements in productivity beyond the classroom setting or standardized assessment.

Significance of the Research

This study holds significant potential in assisting manufacturers and other enterprises with making data-driven decisions regarding the future allocation of training resources. The research could also shed light on content, delivery, and andragogical deficiencies that impede organizations from attaining the expected return on investment. Finally, this project could serve to strengthen relationships so that treatment providers and the recipients work collaboratively to ensure that training goes beyond the classroom/lab experience and credentialing, and directly translates to improved, measurable productivity. The study could become the foundation for future research as manufacturers and labor analysts seek alternative methods to close the skills gap not only in manufacturing, but also other labor sectors.

Purpose of the Research

The purpose of this quasi-experimental study was to determine if a relationship exists between the provision of skill-specific technical education classes and maintenance workers' productivity on the shop floor. Additionally, the research sought a better understanding of whether or not educating (or further educating) incumbent workers is effective in improving the worker's ability to positively impact an organization's productivity by decreasing the amount of time required to diagnose and repair production equipment.

The independent variable was the targeted educational training received by employees already employed as production workers. The dependent variable was the Mean Time to Repair (MTTR) of specified production or training equipment. MTTR is recognized in the manufacturing and equipment reliability communities as a valuable component in determining equipment performance, efficiency, and productivity of a process (Hinchcliffe & Smith, 2006). For this study, MTTR did not include planned and scheduled maintenance activity time as part of equipment downtime.

Quantitative data in the form of MTTR was collected on production training equipment in a controlled lab environment. Incumbent production technicians (subjects) from a local manufacturing facility were given a technical skills assessment using production equipment (having a known component failure) with which they had no prior working experience. The assessment scores served as baseline MTTR data that was compared with MTTR data after an educational intervention had occurred. The subjects were given the treatment (educational training) that exposed the participants to content and competencies relative to industrial equipment and controls. The training equipment used for the treatment was not the same as that used for the assessment so as to evaluate the transfer of knowledge and not teach to the training equipment. The subjects were then reevaluated on the same production equipment used in the pre-assessment with a similar known component failure. Two t-tests were conducted so that the means in test scores and difference-in-means data could be collected and analyzed to determine if a statistically significant change in MTTR occurred as a result of receiving the intervention.

Hypothesis

It was hypothesized that the AIT model would have an impact on the MTTR of mission-critical production equipment as demonstrated by a significant improvement in assessment scores after participants received the intervention. It was also hypothesized that the AIT model would have a greater impact on the MTTR by those participants with prior industrial maintenance experience than those without prior industrial maintenance experience, meaning the subjects with prior maintenance experience would perform better after the intervention than those subjects without prior experience.

Assumptions

The assumptions of this study were as follows:

1. It was assumed that the organization (Company X) offering educational opportunities to the subjects actually placed value on knowing if the educational resources it expends (financial, time, incentive, etc.) render an ROI, and that the outcome of the research would be of significance to the organization's leadership. This assumption was based on the fact that Company X solicited the AIT program as the provider of technical education.
2. It was also assumed a skills deficiency existed among the research subjects and the MTTR on mission-critical production equipment represented a significant and realized loss of revenue for Company X.

3. It was further assumed the assessment equipment used in the study closely represented the actual manufacturing equipment at Company X.

Limitations

The limitations of this study were as follows:

1. The sample size of the subjects tested was relatively small. The participants varied in experience having worked for different manufacturing organizations. Therefore, the results may or may not be able to be extrapolated to other populations.
2. The study's dependent variable could have been potentially influenced by variations in the incumbent workers' prior industrial maintenance experience, their attitudes toward furthering their education, and the incentives offered (if any) to pursue a career as a skilled maintenance technician. The extent to which those variations impacted the dependent variable could become the basis of another research proposal.

Delimitations

The delimitations of the study were as follows:

1. Subjects from regional employers other than Company X were not included in the study in an effort to minimize the impact of variations in processes and complexity of equipment across manufacturing facilities.
2. Subject race, gender, and age were not included in the study as Company X's corporate policy strictly prohibits discrimination based on any of the aforementioned categories and should not be reflected as such in the collection of data.

Definition of Terms

The definitions of terms for this project were as follows:

1. Advanced Integrated Technology (AIT) – Associates in Applied Science (AAS) degree offered at Madisonville Community College (MCC) in Madisonville, Kentucky.
2. Mean Time to Repair (MTTR) – The average time in minutes required to make unplanned and/or unscheduled repairs to mission-critical production equipment.
3. Return on Investment (ROI) – The improvement in productivity in terms of reduced MTTR when compared to resources expended for incumbent worker training.
4. Skills gap – The difference in the skill sets that employees possess compared to employer requirements.
5. Human capital – The combination of the learned process knowledge, previously acquired expertise, and specific skills of a company's employees retained by the employees. Human capital includes employee competencies, commitment, excitement, and loyalty (Campbell, Coff & Kryscynski, 2012).
6. Industrial maintenance technician – A worker who possesses technical knowledge and related skills (electrical, mechanical, information technology, etc.) while providing technical support to the manufacturing equipment and processes in an industrial facility.

Literature Review

The fact that U.S. manufacturing is plagued by a skills gap is undeniable and a review of the literature suggests that the skills gap has been manifesting for over two decades. A skills gap is defined as a void between an organization's labor needs and the skills readily available to help meet those needs, and some see the gap in the U.S. as the Achilles heel of a country looking to grow the economy while restoring its global prominence in productivity (Galagan, 2009). The skills gap in the U.S. became more evident as emerging markets (i.e. China, India, etc.) began gaining a global economic foothold in the 1990s. As these markets experienced economic growth and prosperity, the U.S. sustained and fueled its own economic growth in manufacturing with the use of low- to mid-level skill talent supplied by baby boomers and an influx of women entering the workplaces (McMenimin, 2015).

The gulf that exists between the present workforce's skill set and what is required on a technically advanced shop floor is continuing to widen. In spite of the high unemployment rate resulting from the 2008 global financial crisis, researchers suggest that 125,000 - 600,000 manufacturing positions requiring a middle skill set continue to go unfilled (Mangan, 2013). The disparities in the data can be attributed to the scope in which manufacturing jobs are defined. Some researchers encompass production and assembly jobs that require a minimal skill set as contributors to vacancies, thus inflating the numbers. Conversely, the more conservative data is said to be representative of the number of skilled maintenance technicians who are required to have had specialized training across multiple disciplines.

Still yet, there is literature (albeit less abundant) that suggests a skills gap does not exist at all, but is the result of the incongruence in expected wages by workers and what employers are willing to offer (Baime, 2011). Economic researchers from Iowa State University validated the notion that employers were facing difficulty filling roles in manufacturing, but not as a result of a skills gap in the U.S. In a 2015 report, "Iowa State Researchers Find Little Evidence to Support Skills Gap Claims," researchers stated that if there were a true skills gap in effect, industrial technicians would be working longer hours at increased wages, and statistical data does not support that trend.

There is merit to both sides of the debate as to how a skills gap is impacting the nation's economy, and there are numerous job vacancies currently going unfilled as a result of the perceived skills gap. However, it would be ill-advised to exclude economic conditions the U.S. navigated after the 2008 recession, the timidity with which employers have been approaching their post-recession staffing needs, and the workforce's present skill sets as contributors to the situation (Baime, 2011).

Additionally, middle skills jobs (and desire for these positions) have been reduced as a result of processes becoming automated. The jobs that support automation in manufacturing require much more than middle skills sets. Advanced production equipment and processes require skill sets that are beyond what was sufficient in previous decades of manufacturing, and filling these positions is paramount to closing the gap (McMenimin, 2015). Prior to technological advances in manufacturing processes and equipment, workers with only a high school education, moderate shade tree skills, and the benefit of leveraging nepotism have historically filled maintenance technician positions. With such advances in technology, the bulk of positions are now either in the low-wage, low-skilled or high-wage, high-skilled categories. The middle-skilled worker is either underqualified for highly technical jobs or overqualified for the lower-skilled positions.

Regardless of which end of the spectrum is taken, manufacturers, educators, and policy makers agree that a premium must be placed on education, making it available to the workforce, and skill-specific training that will address the deficit in the supply of workers (Diesing 2012). However, there is a void in information as to how training and education effectively address the skills shortage. Both academia and industry value their respective performance metrics, but those metrics are not aligned. While academia and industry are misaligned in their metrics, they share a common desired outcome: a well-prepared student who will have an immediate impact as a result of their educational experience. The difference is in the way each measures impact.

Upskilling

Strategies to counter the skill shortage have been offered by industry and academia alike with both groups advocating for improvement of incumbent workers' existing skills. For most organizations, the investment made in the employee is frontloaded and signifies the company values and believes in the employee by giving them the opportunity to improve themselves as well as the organization. This approach can foster a mutually beneficial relationship between the employee and employer, and reduces risks by investing in a known, proven entity as opposed to a new hire. Referred to as upskilling, employees are often given the opportunity to improve upon their existing skills to provide new opportunities for increased productivity for the organization and an improved standard of living for the employee (Pace, 2011). Upskilling has most often been the approach of choice to address the unmet need of an employer, and millions of dollars in funding from the federal, state, and local levels are spent annually to address the lack of technical skills needed in manufacturing (Ferraro, 2010).

Educating an incumbent worker presents an invaluable opportunity to improve an organization's workforce and tap their potential. Education can improve an employee's competence and give them a better perspective as to how their role and job duties directly impact a particular industry (Holzer, 2012). This could potentially lead to improved decision making, improvements to a process or product line, and greater dedication to the organization.

However, the time and expense in the form of outlay and production losses often deter companies from pursuing training opportunities. Some will offer that unless a definitive payback can be quantified, the training dollars would be better spent elsewhere. Businesses are often required to evaluate educational opportunities against their core business values by asking, "Are we in business to make a product or educate our workforce?" The answers will vary based on the culture of the organization and the economic climate at that time (Holzer, 2012). Regardless, training and development provide both the company and the employee with benefits that make the cost and time a worthwhile investment (Holzer, 2012).

Depending on the employer, upskilling also describes redefining a job profile to require a bachelor's degree. In these instances, the goal is to capture the highly valued soft skills that typically accompany a bachelor's credential (Salomon-Fernandez, 2014). Changes in manufacturing technology will inherently require upskilling, but this alternate form of upskilling can potentially widen the skills gap by vacating middle skill positions and reassigning individuals with higher credentials to positions of higher skills requirements.

Today's postindustrial, high-tech manufacturers require knowledge-intensive skills and creativity from its workers by working in teams. Manufacturing workforces of today must engage in team-based problem solving, communication/professional behavior development, and process improvement training as well as learning new technical skills (Salomon-Fernandez, 2014). While overall productivity of business units can be measured by output over a given period of time, the measurement of technical training skills is made more difficult as the soft skills are more qualitative than quantitative.

Deskilling

Deskilling is a condition that occurs when specific skill sets are no longer needed to perform a task (Vallor, 2015). Workers who have held positions that traditionally required a bachelor's or master's degree and higher order diagnostic skills have seen their duties turned over to faster and more accurate computerized and automated equipment on factory floors (Bhardwaj, 2013). With advances in automation technology and productivity, physical workloads of employees have also been reduced, and skills that were once required to complete tasks are becoming increasingly obsolete (Salomon-Fernandez, 2014).

Deskilling has progressively occurred as improvements in processes and technology have advanced. American mechanical engineer and process innovator, Fredrick Winslow Taylor, was (unwittingly) one of the pioneers of the deskilling movement with his scientific management approach where workers' duties were broken into strict tasks of detailed instructions. While Taylor's methodology promoted efficiency, it demeaned and dehumanized workers, viewing them as mindless machines instead of cognitive thinkers (Bhardwaj, 2013). Taylor's philosophy also mandated all decision making be taken from laborers and assigned to managers.

Middle skilled workers are often left with the option of upskilling to more technically advanced positions, but usually with significant commitments of time and money from either the employer or employee to complete. Additionally, the closer a worker gets to retirement (as with the case of baby boomers), the less likely an educational endeavor is to occur. To that end, the displaced worker is typically rerouted to a lower-skilled, lower-wage job that has resulted in the forced exodus of middle-skilled workers. This is not to suggest that deskilling is an overt and deleterious movement, nor does the available literature support such, but the results often render the same effect (Clegg, Davies, Kemp, Mueller, & Wall, 1987).

The definition of deskilling also describes overqualified workers (professionals, engineers, etc.) in lower-skilled positions who are unable to find employment in the professional ranks, which underutilizes his or her higher level of professional training. While they may be more qualified than their lower-tiered counterparts in their quest for employment, these individuals' reluctance to fill the middle-skill positions stagnates the effort to close the gap (Gloeckner, Kaminski, & Stone, 2009).

Community Colleges

Employment reports from as early as 2010 have shown that manufacturing has led the economic recovery after the 2008 global financial meltdown. Some attribute the data to then-President Barack Obama's stimulus investment in technical education at the community college level (Pace, 2011). In his State of the Union address, Obama called on community colleges to forge closer ties with local industries for the purpose of designing certificates, degree programs, and apprenticeships to address the skills gap (Baime, 2011). At that moment, community and technical colleges were thrust onto center stage as a means of putting a better educated America back to work and bringing U.S. manufacturing back to its former prominence. As a result, the once held notion that a two-year institution's primary purpose is to serve the underachieving, at-risk student has yielded to one that lauds community colleges as the quickest, most effective, and financially feasible way to put people to work in the positions employers are having difficulty filling. Technical programs that offer credentials (degrees, diplomas, certificates) have been revamped and updated in an effort to quickly address manufacturing's shortfall of qualified employees, specifically the industrial maintenance technician role (Pinchuk, 2014).

Private industry and government funding is being used to create and nurture partnerships between higher education and manufacturers (Krell, 2012). Industry advocate groups and professional organizations such as the Manufacturing Institute (MI), the National Association of Manufacturers (NAM), and the Society of Manufacturing Engineers (SME) collaborate to provide solutions and create pathways that will attract not only high school graduates, but also incumbent workforce members into the world of manufacturing and industrial maintenance (Pace, 2011). Community colleges have been appointed as the education provider to not only create curricula that address the middle skills needed, but also to partner with industry and trade groups to provide equipment and employment opportunities for the students (Pinchuk, 2014). As a result, community and technical colleges have shown themselves to be responsive to industry demands through greater flexibility, the ability to develop skill-specific programs in a timely manner, and awarding specialized credentials.

The issue of closing the skills gap has spurred much debate regarding the most effective way for community colleges to proceed in addressing industry's needs. Accessibility, needs assessments, reassessed SLOs, and credentialing numbers are some of the more concentrated areas of focus that technical schools and their workforce development counterparts consider mission-critical to filling the void (Freifeld, 2013). However, successfully attaining targeted metrics by which colleges are measured does not translate to an ROI (either positive or negative) once a graduate or trainee makes it to the shop floor.

Industry Partners

The image of the community and technical college has begun shifting from one of an educational institution to one of a service provider to meet the needs of industry (Matthews, 2005). However, the contributions most industry partners make toward the relationship with community colleges (financial resources, equipment donations, etc.) cannot be understated. In return, many colleges are dedicating classroom and laboratory space to accommodate hands-on learning of technical skills, many of them industry and job specific. The collaboration is being hailed as a new approach to addressing the skills gap rather than two parties trying to solve the same problem in isolation. If the demands of the 21st century economy are to be met by a skilled and educated workforce, collaborative efforts between employers, labor, industry, and academia must be valued and nurtured (Matthews, 2005).

One such example of a collaborative effort is the $1 million donation that was made to the state of Ohio's community colleges and trade schools by the American Welding Society (AWS) to address the shortage of professional welders available to perform quality work ("Welder workforce," 2006). According to the United States Department of Labor (2017), the number of welding positions is expected to grow in excess of four percent through 2024 with an estimated 15,000 new jobs being created, most of which are in the manufacturing sector. Training and professional development opportunities that were created as a result of the funding helped not only to create a new generation of welders and improve the skillsets of experienced welders, but it also allowed recruitment of high school students directly into the profession. This data could also spur additional research to determine the amount of ROI these organizations are getting from their generosity. One such research question might be, "How many beneficiaries of the AWS funding actually finished their training and are employed as a welder vs. those who took the class, never to weld again?"

Research suggests that larger corporations with greater financial resources are more likely to establish relationships with a community college workforce development entity for contractual training opportunities than smaller companies (Dougherty, 2001). Business and industry value reliable return data to make capital investment decisions. However, little evidence suggests an effective and measurable means of determining an ROI occurs when the community college/workforce development group completes the needed training.

Apprenticeships

Interest has been revived in apprenticeships over the past decade as employers look to fill technically related positions, particularly industrial maintenance technicians. One factor fueling the resurrection is the retirement trend of the baby boomers. Two and a half million baby boomers retired in 2003 and the trend has grown to three and a half million annually as of 2011 (Moten, 2014). The trend is not only creating a shortage of workers, but also an exodus of tribal knowledge gained through years of experience that the baby boomers will take with them. Tribal knowledge represents a body of information that originates (and is improved upon) through informal means in order to improve a product, process, or work condition (Allen, 2013). This information is rarely transcribed into recorded procedural form, but can be passed along to those who may enter into a profession at some point in the future. One method of transferring such knowledge, particularly in the field of maintenance technicians, is through apprenticeships.

Apprenticeships allow the student-employee to transfer the academic knowledge acquired in the classroom to the shop floor and are seen as a major component of the career preparation pathway. The tribal knowledge supplements the student's academic content and experience by learning from past successes and failures of their mentors. Studies have found that employers and workers benefit from apprenticeship training. Workers benefit from higher career earnings and better employability, and employers utilize apprenticeships as a means to meet their demand for skilled workers (Chambers, Eyster, & Lerman, 2009).

The United States Department of Labor (2014) announced a $100 million grant to invest in high-quality, registered apprenticeship programs. However, the apprenticeship programs rely on company sponsorship, and the burden of developing and implementing an apprenticeship program in their facilities, hiring, training, and paying the apprentices falls to the sponsors (Chambers, Eyster, & Lerman, 2009). The ROI for organizations sponsoring an apprenticeship usually comes in the form of a contractual agreement between the sponsor and the apprentice. The arrangement typically guarantees a definitive amount of work in exchange for the education and experience received (Boll, 2014).

Traditional apprenticeships in the U.S. are often viewed as blue-collar, dirty-hands career paths that can be a deterrent when trying to create a pipeline of qualified workers. Historically, these programs have been viewed as an outdated and inflexible form of training. Skilled trade unions have also been accused of placing unwarranted barriers in the path to apprenticeship programs in order to protect the coveted and better paying jobs for union membership (Ayres & Olinsky, 2013).

It has been argued that the apprenticeship approach allows for the most effective means to learn a skill or vocation by combining theoretical and practical on-the-job instruction (Ayres & Olinsky, 2013). However, apprenticeships in the U.S. are not viewed as an integral component of the education curriculum in the secondary or post-secondary systems. More emphasis has been placed on internships and co-op positions that allow short-term familiarization with a job as opposed to multi-year commitments with a greater breadth of experience. To that end, apprenticeship programs have historically been underutilized, ill coordinated, and devalued by parents, students, and policy makers (Jones, 2011).

Research of literature also reveals that in 2007, there were 465,000 apprentices participating in programs across varying fields and industries. The majority of those participating in apprenticeship programs were pursuing careers in health care, construction, automotive technology, machine tool, and child care (Jones, 2011).

Literature abounds on the highly acclaimed apprenticeship model being used with great success in Europe. In European countries, nearly every profession and vocation has an accompanying apprenticeship program that requires completion before students are qualified to enter the workforce (Jones, 2011). Apprenticeships based on this model that tout the experience as prestigious and technically advanced are being adopted in the U.S. The desire for most U.S. manufacturers is to use apprenticeship programs to attract the brighter talent at the secondary level (Boll, 2014). Many U.S. manufacturers and educators are banking on the European model to revive the image of apprenticeships in the U.S., making it a more attractive career track for secondary education students that seek continuance into the postsecondary level. However, if the stigma currently plaguing the U.S. model is to ever be reversed, improving the public's perception of apprenticeships is paramount.

Customized Training Solutions

It is difficult to argue that the community college systems across America positively impact the growth potential of the economy. Community colleges not only provide facilities and specialized training equipment, but also employ industry-seasoned faculty to teach to the specific needs of a business. Economic development has become a major component of community college systems to the point that these entities are part of the colleges' formal budgets and mission statements (Pinchuk, 2014).

Workforce development divisions of community colleges are designed to service the needs of the employers' incumbent workers looking to improve their skills set as well as become eligible for a more desirable position. The training received through company sponsorship is often the first exposure to post-secondary education many will experience (Davidson, 2016). But the workforce development groups were also designed to help enterprises identify and locate the talent needed to sustain their operations. They can provide upskilling in order to secure increased wages within a company, provide individuals with the fundamentals needed to secure a desired position, and bolster the region's attractiveness to garner consideration among those industries looking to relocate or expand their operations (Davidson, 2016).

As companies struggle to manage the needs of their shop floors and the rising cost of training and development, they often turn to their local community college and workforce development partners to meet their workforce needs. Employers are often eligible for financial incentives provided by various government agencies at the federal, state, and local levels. This has become especially attractive as states like the Commonwealth of Kentucky provide deep discounts on training costs through government subsidized grants and other funding.

According to the American Society of Training and Development, companies spent nearly $164 billion in 2012 for training and certificates relative to their businesses (Miller, 2013). Companies often specify particular training needs and have those needs met through specialized and customizable training options. Certificates of completion, college credit, diplomas, or degrees may be awarded for the education received.

By its very definition, workforce development is more than training workers. Workforce development relies on significant employer involvement, a functional and fruitful relationship within the community and its leaders, and network opportunities that promote collaboration among enterprises (Giloth, 2000). Without these contributors assisting with growing a healthy pipeline of future prospects, business and industry will clamor for a continually shrinking pool of qualified workers (Wolfe, 2007).

In spite of the proven benefits of such collaboration, workforce development entities of community colleges will often develop a training program or pathway void of any customer input. In essence, the workforce training group develops the curriculum as they see fit with little input toward development from the customer (Katsinas & Kennamer, 2011). The employer defines the content to be taught, but has little influence on its delivery method or its effectiveness. This is evidenced in the scant availability of data that verifies a training's effectiveness other than the perfunctory survey administered at the close of nearly every training session.

Community colleges with a customized training division, particularly those in the most rural areas, are often the only game in town in terms of training providers for business and industry. The lack of competition further distances them from accountability or performance measures relative to a business's ROI (Bashrum, 2012). Much like academia, workforce development assessment metrics do not typically align with business or production performance metrics that are the engine for decision making among industry customers (Bashrum, 2012). Typically, workforce development metrics measure the quantity of subsidizing grants that are written, the amount of training dollars earned, student headcount enrolled in the training classes, and the number of businesses served within a given service area. As misaligned as the performance measures appear, business and industry training budgets have continued to grow in spite of the unknown impact. In fact, the average training expenditure allotment per employee has increased four percent from each previous year since 2006 (Bostrom, Gupta, & Huber, 2010).

Metrics

Metrics attempt to validate performance or effectiveness by measuring how well goals or objectives are achieved. Opinions vary regarding the use of a quantifiable ROI to measure training effectiveness. This is mainly the result of failing to define training and education objectives at the onset, thereby undermining the validity of the assessment process and making evaluating an ROI difficult at best. Despite the challenges, more industries are beginning to value a hard number to determine if the training effort renders results (Cozzarin, Formaneck, & Percival, 2013).

Industry, particularly manufacturing, uses metrics such as Overall Equipment Effectiveness (OEE), Mean Time Between Failure (MTBF), MTTR, piece count over a period of time, and scrap rate. This information often determines the efficiency of machinery, the effectiveness of processes, and if either are delivering a quality product at the optimum rate. However, some researchers feel a quantifiable value on the output of human capital is difficult to achieve. Variables that influence human output (i.e. attitude toward the task being performed, workplace culture, managerial practices, etc.) affect repeatability and performance. As a result, being able to soundly assess the effectiveness of a particular educational intervention can be difficult at best (Cozzarin, Formaneck, & Percival, 2013).

Academia metrics. Most community and technical colleges measure the value of their education provisions in the form of awarded credentials, adherence to SLOs, college credits earned by the student, minority enrollment, and transfers to four-year institutions to name only a few (Kotamraju, 2011). Exit exams prior to graduation are also administered to measure a prospective graduate's ability to perform fundamental tasks in the workplace of his or her profession. Those results will often provide statistical data that shed insight on how well a student performs when compared to local, state, and national data.

A brief search of peer-reviewed academic journals and dissertations reveals a staggering number of recently written documents on performance-based funding (P-BF) and how to navigate the uncertainty of P-BF's impact on colleges as more and more are being pushed toward this funding model. With increased emphasis placed on P-BF, the focus on ensuring organizations receive a positive ROI on their training investment could fall further down the list of priorities. Unless a college system's goals and objectives specifically include proof-positive ROIs in their business model and corresponding evaluation metrics, the likelihood of quantifiable improvement in customer satisfaction is scant. Colleges and their workforce development entities should purposefully seek to develop key ROI metrics in an effort not only to show quantitative returns on training expenditures, but also to improve on qualitative measures that will fortify the relationships between industry and academia (Cozzarin, Formaneck, & Percival, 2013).

Industry metrics. In industry, ROIs are a bottom line number used as the go/no-go gauge that determines if a business unit will be awarded funding. It also provides justification to shareholders when a business opts to move in a continued or completely different direction (Bashrum, 2012). While investment in human capital exists in industry, education and training are not viewed as investments, but rather as line item expenses (Kirkwood & Pangarkar, 2013). Although industry typically tries to make effective business decisions based on measurable ROIs, the effort to quantify data to determine the ROI on educational expenditures does not appear to be as high of a priority when compared to capital investments.

Literature suggests quantifying the ROI for a company's training effort is more subjective and is difficult to calculate, and some form of expenditure justification should be the expected goal. However, the information comes mostly from a human resource or training provider's perspective and not from a measure of product throughput or equipment efficiency.

Reports from Canadian researchers have been published showing that an objective outcome measure can theoretically quantify an organization's output and even labor productivity (Cozzarin, Formaneck, & Percival, 2013). While the formula appears sound in the quest to quantify training impact, the authors support other research findings that human subjects have an inherent variability when attempting to measure their throughput. Adding to the complexity of the quest are other peripheral influences such as worker IQ, attitudes toward work, attitudes toward the organization by whom they are employed, and the fact that the job tasks vary between the companies that participated in the study (Cozzarin, Formaneck, & Percival, 2013).

Instead, qualitative, subjective assessment tools are used in an attempt to place value on a training experience. In fact, Bashrum (2012) reveals that, while a workforce's measurement of productivity is better than an opinion of a training's impact, it is not practical to obtain. Further, the data created is based on the number of participants whose answers fall somewhere on a Likert scale that is influenced by a myriad of environmental conditions - including fear of identity disclosure.

Summary

Initiatives abound in attempting to address the skills gap in U.S. manufacturing, especially for the middle skills. Strides have been made to close the gap by establishing partnerships between industry and two-year colleges. Various industry organizations, trade groups, and government agencies have provided financial support to expand various initiatives to address the skills gap. However, efforts to quantify the effectiveness of these initiatives remain weak.

Business and industry thrive on quantifiable data when determining if capital investments should be made. Shareholders expect a return from their stock purchases, and if that return is not satisfactory, they will look elsewhere for satisfactory returns. Academia is not beholden to the same metrics and has spent millions of tax dollars, grant funding, and industry contributions on buildings, training equipment, and instructional fees without being able to accurately report a concrete deliverable that industry values.

Emphasis should be on apprenticeships, as they appear to provide the most value in preparing a new pipeline of middle-skilled workers. However, apprenticeships are stigmatized as union-affiliated and outdated, and must undergo a public opinion makeover in the eyes of parents and high school guidance counselors if they are to have a chance of being resurrected in the U.S.

Community colleges and their workforce development counterparts have had the bulk of industry training thrust upon them in the last decade. Partnerships between the colleges and industry have continued to grow while funding and equipment have been made available so that students can experience hands-on learning to supplement the classroom theory. However, the workforce development entities must place greater value on the relationships with their industry partners to better service industry's educational needs.

There is not a lack of available employment for the middle skills in the U.S. Opportunities abound, but the type and level of talent being produced must be appropriate for the vacant jobs. European apprenticeship models avoid such shortages by allowing industry to drive the direction of education and the focus of its pipeline - not the other way around.

Research Method

Overview

A quasi-experiment was conducted with a group of manufacturing employees to determine what effect (if any) an educational treatment had on shop floor productivity. The information gleaned could theoretically be used to determine if an ROI on a training investment (positive, negative, or neutral) is realized. Business and industry typically make investment decisions regarding facilities, equipment, or processes based on whether there will be a quantifiable return on their financial investment. Evidence is typically provided to show the investment will pay for itself over an established period of time, usually in the form of improved throughput from processes or equipment.

Company X was chosen for its location in Western Kentucky and its manufacturing processes used to produce roof support systems specifically for the coal mining industry. Company X made an investment in technical training across several disciplines such as electrical power, fluid power, motor controls, and programmable logic controllers (PLCs). The company had a contractual agreement for training in these disciplines through Workforce Solutions (WS), the workforce development entity of Madisonville Community College. Company X also qualified for KCTCS TRAINS grants, which is state-subsidized funding for the delivery of workforce training and assessment to employers (Lane, 2015). Workforce Solutions partnered with the AIT program for delivery of the modularized online course content. The content was the same for Company X's incumbent workforce as it was for any other traditional or non-traditional AIT student, and the classes taken can be applied as credit toward an Associate's degree in Applied Science in AIT. Provided all other humanities requirements and technical electives are satisfied, an A.A.S. degree is awarded after the successful completion of the AIT curriculum. However, degree completion was not a stipulation of Company X's employee upskilling opportunity.

Company X's end goal was to have the newly educated workforce transfer the knowledge and skills from the classroom to the shop floor and improve upon the metrics with which they measure their performance. Performance, in the case of Company X, was OEE, but for the purpose of this study, the spectrum was narrowed and focused on the reduction of downtime (a variable in calculating OEE). Downtime was considered the amount of time (in minutes) that a mission-critical piece of equipment remained out of service for unscheduled (breakdown) repairs.

The intent of the research was to determine if improvements in MTTR values were able to be established and if the derived information could be used to more effectively allocate training dollars invested by Company X. A reduction in MTTR could indicate to management that the training effort and resources were a sound decision and deserve further funding. An increase in MTTR values would not necessarily have translated to a failed mission but could have identified opportunities for improvement in the training process. Follow-through on such has the potential to render a positive ROI after the improvements are made. It could also potentially lessen the chasm of the two vastly differing performance metrics observed by industry and academia revealed in the review of literature.

Finally, vital information could be gleaned that could help increase the number of qualified maintenance technicians and reduce the number of vacant middle-skill positions. Opportunities for improvement in areas of content delivery, co-requisite learning opportunities, or a stronger focus on partnerships stand to be fleshed out as a result of the findings.

Participants

The group of 21 subjects who initially agreed to participate in this study were all production workers enrolled in AIT classes as part of Company X's workforce improvement endeavor. The classes selected for the group were intended to prepare them for tasks often performed by a multi-skilled technician. A multi-skilled technician is defined as an individual who possesses technical skill sets that qualify them to troubleshoot, diagnose, and repair basic hydraulic, electrical, and mechanical systems used on shop floor production equipment. The group represented a small sample from Company X, which employs approximately 180 full-time workers at their Western Kentucky facility. The participants' ages, levels of experience, and previous education varied.

Critical to note at this point, however, is that 12 of the 21 participants later elected not to participate in the study, leaving only nine subjects for the experiment. Reasons varied from loss of interest, time commitment, and failure to arrive for the experiment at their appointed time. Additionally, the majority of the remaining nine participants had varied levels of technical education in various disciplines such as electrical, mechanical, welding, etc. (See Figure 1).

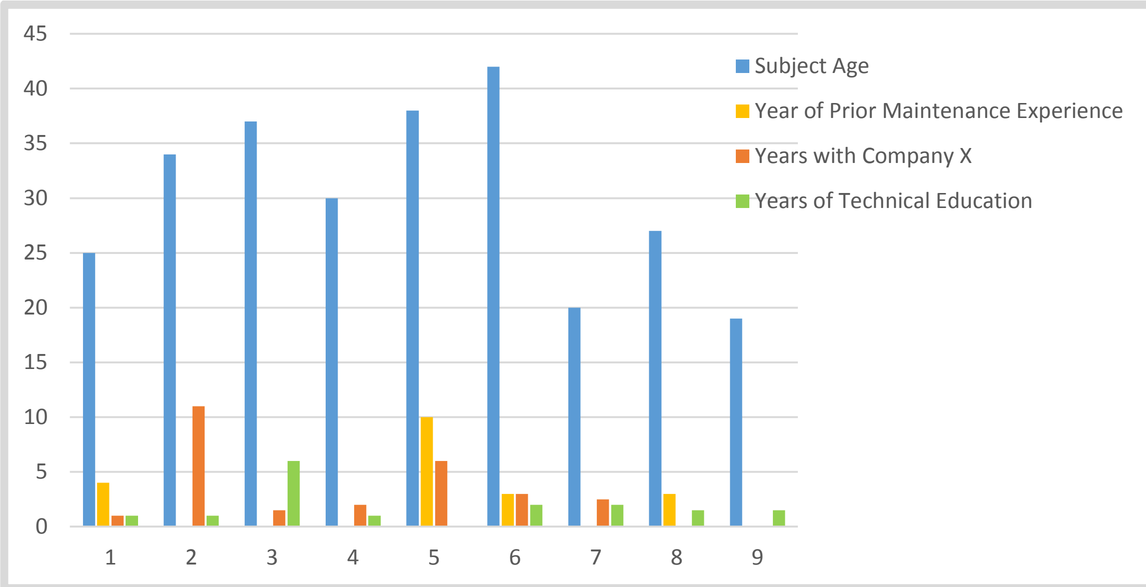

Figure 1. Subject demographic data.

A common denominator among the remaining participants was gender and race as they were all white males. This is congruent with Hopkins County, Kentucky's population demographic that consists of 89.9% Caucasian (USDCB, 2014). Additionally, the subjects had been employed by Company X for an average of three years, averaged 30 years in age, and none of the participants had ever held maintenance technician positions within Company X.

Instruments

The study was a quasi-experiment due to the non-randomized group of participants. The grouping occurred naturally as a result of the common facility in which the subjects work. A questionnaire was given to obtain background demographic data (i.e. age, years of experience, years of post-secondary or trade school education, etc.) on each participant. The information was collected and reported as quantifiable, statistical data.

Company X's downtime data is collected through a Supervisory Control and Data Acquisition (SCADA) system at the facility. The SCADA system allows for real-time calculations that measure OEE and downtime. The information relative to OEE and critical to this study was MTTR. However, a manual means of recording MTTR was used on a piece of simulated production equipment so as to not interrupt mission-critical equipment and processes on the actual shop floor.

A rubric was developed and used to assign participants a score based on the amount of time taken to troubleshoot the machine, diagnose the fault, correct the fault, and return the machine to service while observing safety procedures throughout the entire process (See Appendix). Points were awarded according to the time intervals in which the subjects successfully completed a task, and a 20-minute time limit was placed on the experiment.

Variables

There were three anticipated variables that impacted the quasi-experiment. They were as follows:

- Dependent variable: the MTTR data that came from the production equipment.
- Independent variable: the educational treatment in the form of AIT classes that addressed skills deficiencies in one group of production workers.
- Mediating variables: the age, level of completed education, and maintenance experience prior to being employed by Company X.

It was hypothesized that the dependent variable would be impacted by the independent variable with the strong possibility of the mediating variables affecting the results. It was further hypothesized that the mediating variables could skew the repeatability (and subsequently the extrapolation of the results of the study) given the subjective and unpredictable nature of human test subjects.

Procedures

Each subject was given critical information (i.e. schematics, operating procedure documents, etc.) relative to a piece of production equipment that had faulted; a verbal description of how the machine was designed to operate; a verbal summary of the manner in which it was operating when a random fault occurred; hand tools; and a digital multi-meter for electrical measurement. As soon as instructed by the researcher, the subject began troubleshooting and repairing the machine while the researcher timed the activity. The amount of time (in minutes) required to return the piece of equipment back to service was recorded as the MTTR. Each participant's troubleshooting skills were assessed to determine their baseline MTTR on the piece of production equipment with which they had no prior knowledge or familiarity.

The subjects were then administered the intervention in the form of two AIT troubleshooting learning modules: Introduction to Troubleshooting and System Troubleshooting, both of which had content delivered online with hands-on learning in the AIT lab. It should be noted that the equipment used in the learning modules was not the same equipment used in the baseline assessment, nor was it similar other than in general function. In this way, a transfer of knowledge could theoretically occur and have been demonstrated rather than the subjects learning the trainer.

All troubleshooting lectures, reading assignments, critical thinking exercises, digital learning objects, and class-related assessments were administered via computers made available at Company X and MCC. The hands-on, in-person lab component was designed to reinforce the online content and allowed for face-to-face interaction with AIT faculty in the lab as needed. At the conclusion of each lab session, the subject took an open-book, online assessment. The method of delivery and assessment was the same for each AIT class that the subject was required to take.

After the two troubleshooting modules were administered in their entirety, the same assessment was given to the same group of subjects on the same equipment, with the random fault being moved to another component. As with the pre-intervention assessment, participants were scored based on the amount of time taken to troubleshoot the machine, diagnose the fault, correct the fault, and return the machine to service while observing safety procedures throughout the entire process.

Measures and Analysis

The purpose of the quasi-experiment was to measure changes in the MTTR on production equipment returned to service by subjects who received the educational treatment. Comparisons were made between the pre-treatment (baseline) and post-treatment data to determine if there was an appreciable change in the MTTR within the treated group. Points were awarded based on the time intervals in which the subjects successfully completed a task, with a 20-minute time limit placed on the experiment. A higher number of points on the assessment indicated there was a decrease in the minutes of MTTR on the machine. The differences in the participants' MTTRs were recorded for statistical analysis (See Tables 1 and 2).

Table 1

Subject pre- and post-intervention scores

	Scores		
Subject	Pre-Intervention	Post-Intervention	Difference
1	40.00	75.00	35.00
2	35.00	90.00	55.00
3	40.00	75.00	35.00
4	40.00	90.00	50.00
5	50.00	75.00	25.00
6	30.00	30.00	00.00
7	45.00	75.00	30.00
8	40.00	45.00	05.00
9	40.00	40.00	00.00

Table 2

Subject pre- and post-intervention scores descriptives

	Scores		
Statistic	Pre-Intervention	Post-Intervention	Difference
Mean	40.00	66.11	26.11
Median	40.00	75.00	30.00
Mode	40.00	75.00	35.00
SD	05.59	22.05	

Note. SD = standard deviation.

A paired t-test was used to compare the mean values of two sets of data: the pre-treatment scores and the post-treatment scores. From the data, an analysis was conducted to determine if the treatment was effective at decreasing the MTTR value on the equipment.

In addition, a second analysis was used to determine if a subject's prior maintenance experience impacted the efficacy of the treatment. In the second analysis, participants were categorized based on their prior maintenance experience (Group 1: <12 months of maintenance experience, Group 2: >/= 12 months of maintenance experience), and a difference-in-means t-test was performed on the data to determine if there was a significant difference in the means between the two groups. An alpha level of .05 was used for each of the hypotheses.

It was hypothesized that the paired t-test would yield a statistically significant difference in the mean pre-treatment and post-treatment assessment scores at the .05 alpha level, allowing for the rejection of the null hypothesis and the acceptance of the alternate hypothesis (Ha: $\mu_1 \neq \mu_2$). Further, it was hypothesized that the difference-in-means t-test would yield a statistically significant difference in the mean change in scores between those individuals with prior maintenance experience and those without prior maintenance experience at the .05 alpha level, also allowing for the rejection of the null hypothesis and the acceptance of the alternative hypothesis (Ha: $\mu_1 \neq \mu_2$).

Threats to Validity

There were inherent internal threats to the validity of the results with this study. The inherent nature of human subjects provided a challenge when attempting to build repeatability. Problems internal to Company X, the subject's view of furthering their education (intimidation, acceptance, etc.), home life or health-related issues, consequences of failure, etc. all had the potential to significantly impact the research's repeatability. Every effort to minimize outside influence and nullify these threats was made. Such examples included assessment and experiments being conducted away from Company X to minimize interruptions, the use of standardized questionnaires, and utilizing different assessment equipment from that used during the treatment.

The relatively small sample size of the group made it difficult to accurately generalize the results to a broader population. Additionally, if the study were recreated over a longer period of time, any subjects who left Company X for employment elsewhere could have possibly skewed the data and shown an increase in cost of training for Company X. Such action would have diminished the chances of achieving a positive ROI as a result of the employee's departure, thereby equating to a possible loss. The amount of theorized loss depends on how soon after the treatment the subject leaves Company X. The longer the subject stayed after the company-sponsored education, the more of the investment Company X would expect to theoretically recover. This threat to validity was given serious consideration since manufacturing in MCC's service area has been in decline since the 1990s. This has resulted in maintenance technicians going from one company to another, thereby allowing one company to benefit from another's outlay of training dollars.

Results and Findings

Data Summary

A two-tailed, single-sample, paired t-test was used because the same group of participants were being assessed at two different points in time. The test concluded that the mean difference between pre-test scores and post-test scores was 26.11 points higher than the null hypothesized population mean of zero (See Figure 2).

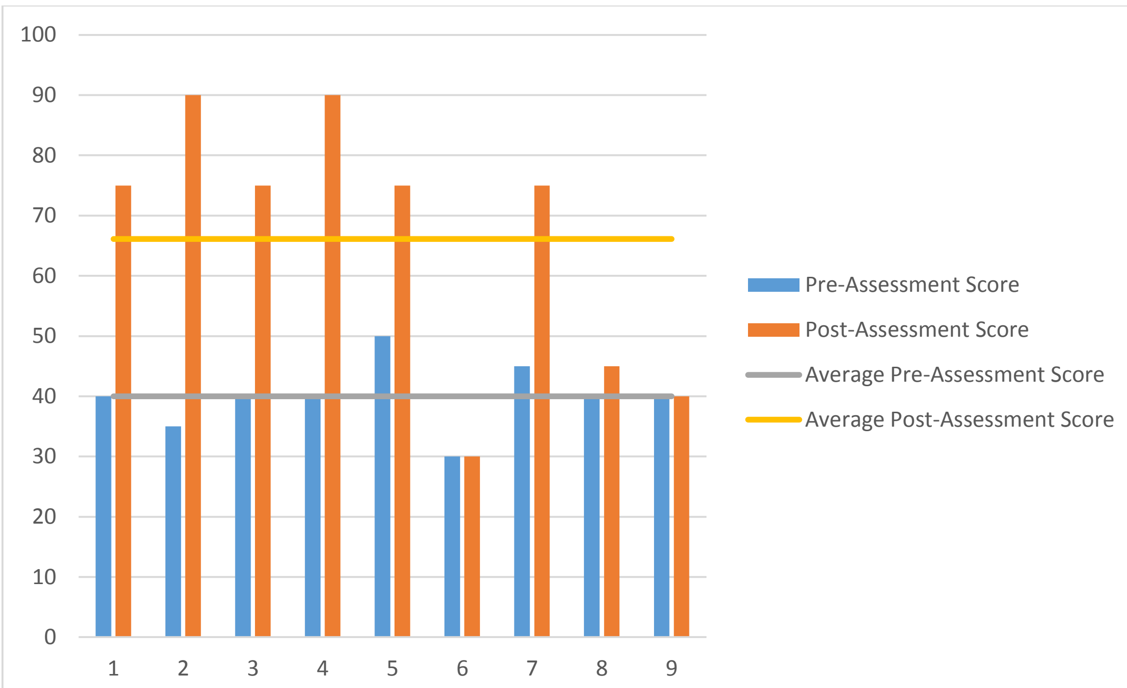

Figure 2. Pre- and post-assessment scores mean differences.

Analysis yielded a t-crit value of +/- 15.82, which suggested with 95% confidence that the true mean difference between pre-test scores and post-test scores was expected to fall within the confidence interval of 10.29 and 41.93, which is greater than the null value of zero. Therefore, the null hypothesis was rejected for this portion of the analysis. The probability of obtaining a random sample of nine students with a mean as large as or larger than the one found in this sample is 0.005, which is less than the alpha of 0.05. As a result, the likelihood of zero being the true mean value of the difference between pretest scores and posttest scores was rejected (See Table 3).

Table 3

Two-tailed, single-sample, paired t-test

Mean score change	t-test	t-crit	95% CI
26.11	3.8059*	+/- 15.82	[10.29, 41.93]

Note. CI = confidence interval.
*p < .005.

A two-sample, two-tailed, difference-in-means t-test was used to compare the mean score change of the participants who had prior maintenance experience with those who did not have prior maintenance experience. The results revealed that the difference in mean score changes of pre-test scores and post-test scores between participants with prior maintenance experience and participants without prior maintenance experience was 4.25 points higher than the null hypothesized population mean difference of zero (See Figures 3 and 4).

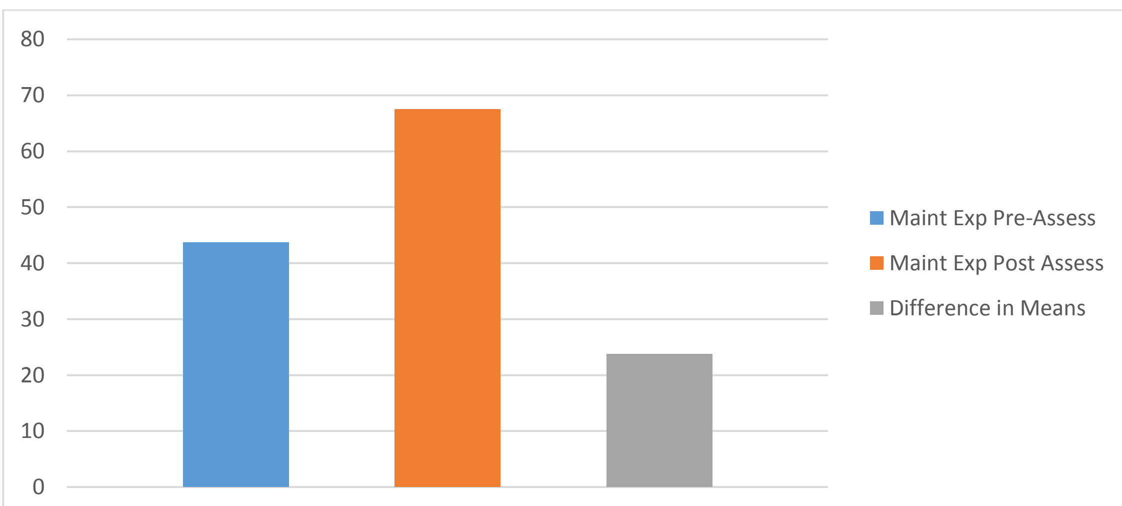

Figure 3. Pre- and post-assessment score means: Subjects with maintenance experience.

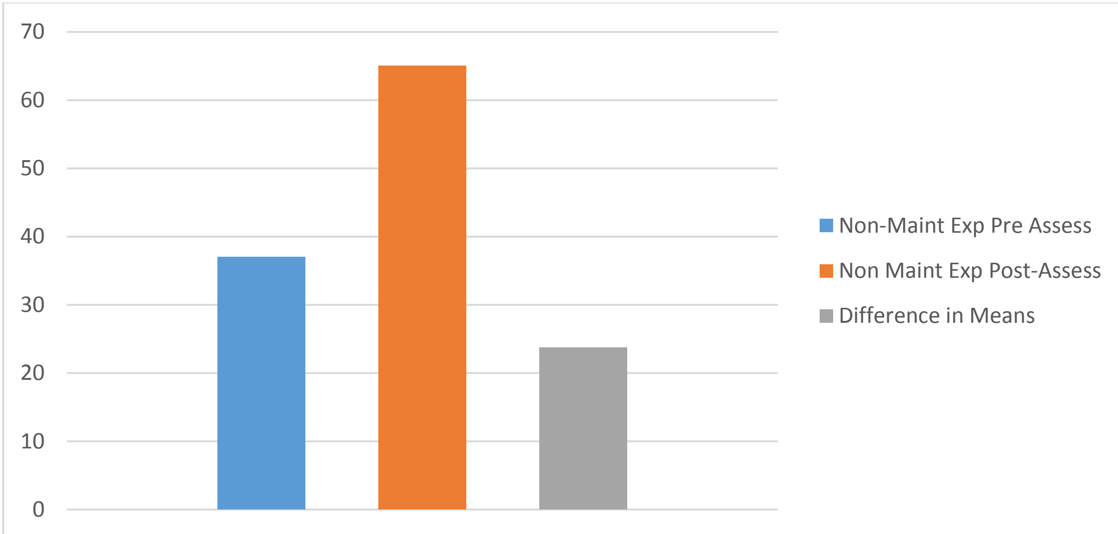

Figure 4. Pre- and post-assessment score means: Subjects without maintenance experience.

The probability of obtaining a random sample of four participants with maintenance experience and five participants without maintenance experience with a difference in mean differences as large as or larger than the one found in this sample was .7805, which is greater than the alpha value of 0.05. Therefore, the probability of zero as the true difference in mean differences of pre-test scores and post-test scores between participants with maintenance experience and participants without maintenance experience could not be rejected. Furthermore, the t-crit score of +/- 34.69 yielded a 95% confidence interval of -30.44 and 38.94, which contains the null hypothesized value of zero (See Table 4).

Table 4

Two-tailed, two-sample, difference-in-means t-test

Difference-in-means	t-test	t-crit	95% CI
4.25	0.2897*	+/- 34.69	[-30.44, 38.94]

Note. CI = confidence interval.
*p < .005.

Conclusion

In its broadest terms, this thesis originated from a desire to learn whether or not companies are making wise use of financial and human resources when investing in incumbent workers' education as a means to fill the skills gap that is plaguing shop floor output. The research also sought to determine if educating the incumbent production worker with previous maintenance experience rendered better MTTR scores as opposed to incumbent production workers with no previous maintenance experience.

A statistical analysis of data rendered from a two-tailed, single-sample, paired t-test showed (with 95 percent confidence) that the MTTR on mission-critical equipment can be positively affected after the workforce has been exposed to relative technical subject matter, thereby supporting the first hypothesis. However, the data collected and analyzed from a two-tailed, two-sample, difference-in-means t-test suggested that prior maintenance experience among the subjects had no bearing on the assessment scores after the intervention. As a result, the second hypothesis of this study was not supported.

The unexpected decline in sample size has left questions as to whether the results can be extrapolated to a larger population. This research could be expanded to future studies that would take into consideration the incumbent workers' attitude toward additional education and desire to advance in a profession. It is surmised that those variables could play a significant role in determining which incumbent worker is best suited to receive the allocation of technical education dollars.

As the project matured, a recurring theme began to surface that begged the question, "Why have companies historically continued to fund the education of incumbent production workers as a condition of employment without a better sense of the expected outcome?"

What remains is the fact that companies would be better served if there were a quantifiable, formulaic approach to determine which incumbent workers would provide the better ROI on their training dollar. Unlike machines however, human subjects have inherent variables that may make such a scenario difficult (if not impossible) to create.

Recommendations for Further Study

As organizations search for new means of being more competitive and profitable, the research gleaned from this project could be used as a model for future experiments that would quantify the incumbent workers' desire to advance into a technical role and their likelihood to succeed in a maintenance technician position. This would allow businesses to pinpoint potential in prospective candidates, better allocate training resources, and eliminate efforts to herd those without desire or aptitude into positions for which they are ill-suited.

While business and industry use quantifiable data to make decisions regarding financial and natural resources, the variables that are inherent to human resources (attitude, stress level, view of management, etc.) are more difficult to quantify, thus making data-driven decisions regarding workforce investment a challenge. As such, there is potential for future research to create a formula that generates more quantifiable human resource data so that sound investment decisions can be made with more confidence, and a return on an organization's investment in the workforce can be realized.

Further research could potentially develop a formulaic approach for determining a breakeven point to evaluate how long an employee must remain with an organization before it recoups its cost for intervention. There is also potential for determining if a range in employee characteristics exists when evaluating a prospective technician's demographic data (age, experience, education, etc.). This could theoretically place the most-suited person in the role of a maintenance technician with a greater chance of success, thereby increasing the likelihood of a positive ROI on an organization's training dollar.

Future research is also recommended to determine if post-secondary and industry metrics could become better aligned to ensure the customer (industry) is being served to the best of the provider's ability. This collaboration will provide a synergistic approach to finding success as opposed to running in opposite directions.

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APPENDIX

Pre- and Post-Intervention Grading Rubric

Subject ID #:	**Date:**	**Start Time:**	**Finish Time:**	
Rubric Criteria	**4 x 5 points**	**3 x 5 points**	**2 x 5 points**	**1 x 5 points**
Checked System for Overall Functionality	*Within two minutes of commencement of test*	*Between two and five minutes of commencement of test*	*Between five and ten minutes of commencement of test*	*Between 10 and 20 minutes of commencement of test*
Troubleshoot and Diagnose Equipment for Failed Component	*Within two minutes of commencement of troubleshooting*	*Between two and five minutes of commencement of troubleshooting*	*Between five and ten minutes of commencement of troubleshooting*	*Between 10 and 20 minutes of commencement of troubleshooting*
Repair Failed Component	*Within two minutes of commencement of repair of failed component*	*Between two and five minutes of commencement of repairing failed component*	*Between five and ten minutes of commencement of repair of failed component*	*Between 10 and 20 minutes of commencement of repair of failed component*
Operationally Check Repair and Return to Service	*Within two minutes of re-energizing equipment after repair of failed component*	*Between two and five minutes of re-energizing equipment after repair of failed component*	*Between five and ten minutes of re-energizing equipment after repair of failed component*	*Between 10 and 20 minutes of re-energizing equipment after repair of failed component*