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The development and evaluation of a lean six sigma advanced manufacturing methodologies course for aeronautical engineering technology curriculum

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For the degree of Doctor of Philosophy

Is approved by the final examining committee:

James P. Greenan
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James M. Brown

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Approved by Major Professor(s): James P. Greenan

Approved by: Janet M. Alsup 12/5/2016

Head of the Departmental Graduate Program Date

THE DEVELOPMENT AND EVALUATION OF A LEAN SIX SIGMA ADVANCED MANUFACTURING METHODOLOGIES COURSE FOR AERONAUTICAL ENGINEERING TECHNOLOGY CURRICULUM

A Dissertation

Submitted to the Faculty

of

Purdue University

by

John Michael Davis

In Partial Fulfillment of the

Requirements for the Degree

of

Doctor of Philosophy

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Thanks to the good Lord for giving me the strength and ability to complete this project one day at a time. To my amazing wife Heather, thank you for your personal support, undeniable patience, and for being by my side for this extraordinary journey. Thank you to my family, friends, and colleagues who supported me through the last three years and provided me the strength to persevere. Special thanks to my committee members for their guidance and leadership in conducting this study that has helped me to develop my research knowledge and skills.

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ABSTRACT

Davis, John M. Ph.D., Purdue University, December 2016. The Development and Evaluation of A Lean Six Sigma Advanced Manufacturing Methodologies Course for Aeronautical Engineering Technology Curriculum. Major Professor: James P. Greenan.

Successful completion of the Lean Six Sigma advanced manufacturing methodologies practicum course provides undergraduate Aeronautical Engineering Technology (AET) students with the experience and knowledge appropriate to perform successfully in an advanced manufacturing environment. Therefore, the purpose of this study was to determine (a) Did the knowledge level of AET students increase following exposure to Lean Six Sigma and completion of the advanced manufacturing methodologies course? and (b) Did the course meet the AET students' expectations following participation in the Lean Six Sigma advanced manufacturing course? The expected outcomes of the course included:

1. AET students will have the competencies to utilize required advanced manufacturing processes to operate a manufacturing facility.
2. AET students will have the ability to utilize advanced process quality planning methods to implement a quality program in a manufacturing facility.
3. AET students will have the knowledge and experience required to effectively implement supply chain management techniques and logistic programs in a manufacturing facility.

4. An effective continuous improvement process will be utilized and promoted throughout the curriculum.

Currently, students are using the lab space in the School of Aviation and Transportation Technology (SATT) to perform practical hands-on projects related to their aviation major. This study required undergraduate AET students to receive instruction in logistics, quality, and manufacturing terms and descriptions. Students utilized the information learned and basic lean manufacturing and continuous improvement philosophies to complete course projects. The course projects included a focus on transforming the School's powerplant laboratory into a more typical aerospace manufacturing cell layout, enabling students to explore ways of operating an advanced manufacturing facility. Students in the advanced aviation manufacturing course developed and implemented manufacturing simulations. This study focused on developing a world-class course utilizing an operating laboratory facility to prepare future aviation manufacturing professionals with industry leading skill sets. This study was used to gather data for the development and evaluation of a Lean Six Sigma advanced manufacturing course with future goals of scaffolding with other SATT courses to provide a minor for the AET curriculum in advanced aviation manufacturing. The findings of the study indicated that student knowledge levels of Lean Six Sigma methodologies increased significantly after receiving instruction. Additional findings of the study revealed that students felt the course met their expectations. However, due to several limitations of this study, further research is recommended in focused areas to provide students the tools to compete in the aviation and advanced manufacturing world.

CHAPTER 1: INTRODUCTION

Nature of the Problem

The Bachelor of Science in Aeronautical Engineering Technology (AET) program in the School of Aviation and Transportation Technology (SATT) at Purdue University is an ABET-ETAC (formerly Accreditation Board for Engineering and Technology and the Engineering Technology Accreditation Commission) accredited curriculum. It is the responsibility of the AET program to demonstrate that the ABET-ETAC accreditation criteria are met. For this reason, this study is a valuable asset, immediately usable within the AET plan of study. As this effort matured, it benefitted AET students by directly involving them in helping create an updated laboratory learning environment, while researching both existing and new manufacturing technologies through immersive learning projects (Gay, 1987).

The ABET-ETAC accreditation planning process must include three of the eight criteria required for accreditation. The first section is ABET-ETAC Criterion 2: Program Educational Objectives. This program must provide program educational objectives that are consistent with the mission of the institution, the needs of the program's various constituencies, and the accreditation criteria (ABET-ETAC, 2016). There must be a documented, systematically used, and effectively implemented process involving program constituencies for the periodic review of the program's educational objectives that ensure they remain consistent with the institutional mission, program's constituents' needs, and criteria (ABET-ETAC, 2016).

The second section is ABET-ETAC Criterion 3: Student Outcomes. The program must have documented evidence of student outcomes that indicate graduates have achieved the program's educational objectives. There must be a documented and effective process for the periodic review and revision of the student outcomes (ABET-ETAC, 2016). Student outcomes that must be met by the AET degree program were derived from the ABET-ETAC criteria and include:

- Ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities.
- Ability to select and apply knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies.
- Ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments.
- Ability to apply project-based learning techniques to improve processes, and communicate a commitment to quality, timeliness, and continuous improvement. All the objectives listed are crucial in the manufacturing world.

The third section comprising assessment planning is ABET-ETAC Criterion 4: Continuous Improvement. This program must regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being successfully attained. The results of these evaluations must be systematically utilized as input supporting the continuous improvement of the overall program (ABET-ETAC, 2016).

The program must demonstrate that the technical, scientific, and managerial areas of expertise developed by graduates are appropriate to the professional orientation and goals of the program. The outcomes for the Bachelor of Science in AET program stipulate that graduates have the technical expertise in engineering materials, statics, strength of materials, applied aerodynamics, applied propulsion, and either electrical power or electronics. Graduates should also possess the expertise in a minimum of three subject areas. The subject areas are manufacturing processes, vehicle design and modification, engineering materials, electromechanical devices and controls, industrial operations, and systems engineering including the appreciation of the engineering design cycle and the system life cycle relating to the manufacture and maintenance of aeronautical/aerospace vehicles and their components (ABET-ETAC, 2016). Lastly, AET graduates must have expertise in applied physics.

The use of advanced manufacturing methodologies is not well documented in undergraduate programs (ABET-ETAC, 2016). The absence of documentation or implementation of Lean Six Sigma manufacturing techniques into the undergraduate Aeronautical Engineering Technology education experience raises three questions. What would be the validity and reliability of a Pre-test/Post-test instrument used for the assessment of student knowledge levels? Would the knowledge level of AET students increase after successful completion of a Lean Six Sigma advanced manufacturing methodologies course? How well would the course meet the AET students' expectations after participating in the Lean Six Sigma advanced manufacturing course?

This study, therefore, examined the plan of study requirements and performed a needs analysis for the baccalaureate Aeronautical Engineering Technology program. There was a need to assess the appropriateness of adding a Lean Six Sigma manufacturing course to the curriculum. Accordingly, this study attempted to prepare a curriculum to better equip SATT graduates for careers in 21st-century aviation.

Statement of the Problem

With the utilization of ABET-ETAC criteria objectives to expand the AET programs, the School of Aviation and Transportation Technology seeks to prepare graduates to enter more diverse and challenging career paths throughout the global aviation arena. Additionally, the School of Aviation and Transportation Technology's Industry Advisory Board has expressed concern about the extent of exposure to leading industry practices to which the student population in Aeronautical Engineering Technology is exposed. The major problem of this study, therefore, was to assess the existing curriculum and formulate recommendations for the stakeholders concerning the preparation of AET students to successfully meet the challenges of a modern, dynamic aerospace advanced manufacturing environment. The stakeholders for this study included the School administration, faculty, and most importantly, students in the SATT.

Purpose and Objectives of the Study

The purpose of this study was to develop and evaluate Lean Six Sigma advanced manufacturing methodologies for the Bachelor of Science in AET curriculum, utilizing a course tailored specifically towards training and education of future aviation manufacturing professionals. Using aerospace practices and equipment as a centerpiece, the course and learning space were designed for fit and collaboration with other manufacturing curricula as well. Multiple global sourcing supply chains and collaboration with diverse professional technical groups from varying disciplines are the standard in the current advanced manufacturing environment across many technology industries. Accordingly, this course was designed to accommodate not only aviation students, but students from other manufacturing disciplines as well. The ultimate outcome was to develop an Aeronautical Engineering Technology course that could provide students the opportunity to learn and apply advanced manufacturing techniques (specialized as well as collaborative) relevant to the aviation industry. This activity enables the completion of the student learning experience with a practical application of manufacturing technologies. Students could eventually have the opportunity to take this course as a minor concentration in advanced manufacturing. Upon successful completion of the advanced aviation manufacturing course, students would be expected to possess the necessary knowledge and experiences to function effectively in an advanced manufacturing environment.

The objectives established for this study, therefore, included:

1. AET students will develop the competencies required to effectively utilize advanced manufacturing processes to successfully operate a manufacturing facility.
2. AET students will acquire the knowledge and skills required to effectively utilize advanced process quality planning methods to successfully implement a quality program in a manufacturing facility.
3. AET students will increase their knowledge and experiences to successfully implement supply chain management techniques and logistic programs in a manufacturing facility.
4. AET students will promote and implement a continuous improvement process that will be successfully utilized throughout the curriculum.

Research Questions

To develop and evaluate the Lean Six Sigma advanced manufacturing methodologies course in the Bachelor of Science in AET undergraduate curriculum, the following research questions were posited for this study:

1. Did the knowledge level of AET students increase following exposure to Lean Six Sigma and completion of the advanced manufacturing methodologies course?
2. Did the course meet the AET students' expectations following participation in the Lean Six Sigma advanced manufacturing course?

Significance of the Study

By utilizing the ABET-ETAC criteria objectives to expand the AET program, the School of Aviation and Transportation Technology seeks to better prepare graduates with knowledge, problem-solving ability, and project-based learning (hands-on) skills to enter careers in the design, installation, manufacturing, testing, evaluation, technical sales, or maintenance of aeronautical/aerospace systems. The level and scope of career preparation depend on the program's plan of study and the AET-specific program orientation. Since this program is a baccalaureate degree program, graduates typically have strengths in the analysis, applied design, development, implementation, or oversight of more advanced aeronautical/aerospace systems and processes (ABET-ETAC, 2016).

ABET-ETAC PEOs – Program Educational Objectives (PEO) were utilized and evaluated as part of the development process. The five PEO's were used as a minimum in this study to develop the course material:

- PEO 1- Effectively apply technical knowledge, problem-solving techniques, and hands-on skills in traditional and emerging areas of aerospace design, manufacturing, operations, or support.
- PEO 2- Be active and effective participants in ongoing professional development, professional growth, and increasing professional responsibility.
- PEO 3- Effectively communicate ideas to technical and non-technical people.
- PEO 4- Work effectively in industrial teams.
- PEO 5- Work within the accepted standards of professional integrity and conduct.

Student Outcomes (SO) were also required as part of the development process and included the following (ABET-ETAC, 2016):

- Demonstrate the appropriate mastery of aerospace processes and technology to apply problem-solving tools and techniques and hands-on skills for the design, manufacturing, operations, and support of aerospace vehicles or vehicle systems.
- Apply and adapt the appropriate mathematics, science, engineering, and technology in problem definition and problem solutions.
- Demonstrate an ability to evaluate and identify problems, perform testing and measurement to understand problems, and to interpret the results of testing and evaluation to successfully recognize and develop appropriate solutions and outcomes.
- Demonstrate an understanding of the aerospace vehicle as a system, and its role as a part of a greater system, and to develop creative solutions which positively impact related system components.

- Demonstrate the ability to collaborate effectively in a teaming environment, and utilize the tools necessary to communicate, collaborate, mentor, and appropriately lead in a team environment.
- Apply appropriate technical and decision-making tools to successfully identify, analyze, and solve problems.
- Demonstrate effective written, oral, and presentation skills appropriate for leadership and cross-functional communication.
- Demonstrate the skills to learn independently, and to understand the necessity for continued learning.
- Demonstrate an ability to understand professional, ethical, and social responsibilities.
- Demonstrate an understanding for the importance of diversity and knowledge of contemporary professional, societal, and global issues.
- Demonstrate a commitment to quality, timeliness, and continuous improvement needed to perform to an aerospace quality standard.

The Program Educational Objectives (PEO) are educational objectives that describe what students/graduates are expected to attain within a few years after graduation from the program. The objectives are based on the needs of the program constituencies. The Student Outcomes (SO) describe what students are expected to know and be able to demonstrate by the time of graduation. The outcomes relate to the skills, knowledge, and behaviors that students acquire as they progress through a program.

Delimitations of the Study

The study had two major delimitations. First, participant selection was limited to enrolled Aeronautical Engineering Technology students. Selection was based on only a two-year period, for development and evaluation of the Lean Six Sigma advanced manufacturing objectives for the course. The second delimitation was the ability to incorporate project-based learning objectives into the Lean Six Sigma advanced manufacturing course as required to enhance the course. The study's methods and procedures were selected and implemented around these delimitations.

Assumptions of the Study

The focus of this study was to provide a project-based learning experience for Aeronautical Engineering Technology students. It was assumed that providing education in Lean Six Sigma manufacturing methodologies, undergraduate students would be able to demonstrate those key Lean Six Sigma skills desired by industry and, therefore, be better prepared to successfully enter the workforce. This study also assumed that respondents would be able to recall and apply detailed information from the Lean Six Sigma course materials. Finally, it was assumed that the respondents would be candid and truthful when responding to the survey items.

Definition of Terms

5S: "An organized workplace consisting of a setting where tools, work instructions, and processes are orderly and consistently in the same place all the time." As described and detailed by Ramesh, Prasad, and Srinivas (2008), the Toyota Production System and lean implementation begin with 5S concepts as the foundation. "Each S

(*Sort, Straighten*, *Shine*, *Standardize*, and *Sustain*) is a separate entity unto itself and should be implemented in steps with input from the workforce to ensure that 5S efforts are sustained."

Lean Six Sigma Manufacturing: "A manufacturing paradigm using all tenets of the Toyota Production System and empowering employees; while constantly looking to improve throughput, efficiencies, and visual management." These improvements can also be seen as cost-effective measures. Brown, Collins, and McCombs (2006) described Lean manufacturing as the desired methodology in manufacturing since there is a constant effort to attain zero waste in the system.

DMAIC Process: A lean and quality Six Sigma tool that was defined by Brown, Collins, and McCombs (2006). "The DMAIC Process allows a company to use a scientific approach when implementing a lean manufacturing system." The steps--Define, Measure, Analyze, Improve, and Control each have specific criteria that must be met before a project or implementation phase can move forward." The ultimate goal is to arrive at the control stage so that an improvement is then actually a part of everyday business for a company. Each step in the process is accompanied by small Kaizen events to ensure employee involvement.

Kaizen (Continuous Improvement): Kaizen, as defined by Brandt (2007), "is the process of achieving small improvements to processes and the work environment through hourly worker and management interaction and discussion." "Kaizen events are routinely performed to both initiate change (brainstorm), and to update the stakeholders as to a project's process and performance." Kaizen events can be seen in baseball terms as hitting a series of singles to score a run instead of trying to hit a home run all the time.

The focus is on small incremental improvements that involve all levels of an organization and being able to sustain each step in the lean journey.

Kan Ban: “A primary philosophy of lean manufacturing is to produce only what the customer requires in the timeframe and quantity that is necessary.” As illustrated by Ohno (1988), “Kan Ban and Kan Ban systems are designed to attain a lean and cost-efficient state of material flow from the point of raw materials to finished goods and shipping to the customer.” Kan Ban systems can be electronic, visual, or use cards as the means of status indication. “The key ingredient to the Kan Ban system is that a signal is sent to a downstream process to make or send more products, or stop production or shipping due to the status of the system (empty or full).” Because of the importance of maintaining appropriate process and cost controls, Kan Ban is often considered the most important part of all lean implementation planning and projects (Ohno, 1988).

CHAPTER 2: REVIEW OF THE LITERATURE

The literature review discussed and summarized information on the origins of Lean Six Sigma and Lean Six Sigma methodologies. It was important to demonstrate how these tools have been employed to increase productivity efficiencies and bottom line profit improvements. The review also encompassed Lean Six Sigma methodologies for development and evaluation of curriculum. Exploration of opportunities to implement Lean Six Sigma tools into the Aeronautical Engineering Technology undergraduate curriculum was also included. It is believed that by offering Lean Six Sigma advanced manufacturing methodologies to AET students would better prepare them to enter the advanced aviation manufacturing workplace (Johnson & Dubikovsky, 2008).

Definition and Origins of Lean Six Sigma

The quest to achieve Six Sigma had its beginning at the Motorola Corporation in 1979 when executive Art Sundry proclaimed at a management meeting, “The real problem at Motorola is that our quality stinks!” Sundry’s proclamation initiated a new era within Motorola and led to the discovery of the important association between higher quality and lower development costs in manufacturing products (McFadden, 1993).

At a time when most American companies believed that quality costs money, Motorola realized that if implemented correctly, improving quality would reduce costs. They thought that high-quality products should cost less to produce, not more. They reasoned that the highest-quality producer should be the lowest-cost producer. At the time, Motorola was spending 5 to 10 percent of annual revenues, and in some cases as much as 20 percent of revenues, correcting poor quality. That translated into $800 to $900 million each year, money that, with higher-quality processes, could be returned directly to the bottom line. Motorola's belief that high-quality products should cost less to produce has since been proven over and over again to be true (Pande, Neuman, & Cavanagh, 2001).

A quantum leap in manufacturing technology occurred at Motorola when it applied Six Sigma to the development of its Bandit pager – a name the company selected because those persons involved in the project "borrowed" every good idea they could find from products already on the market. Within 18 months, and for a price tag of less than $10 million, Motorola's 23 Bandit engineers had designed a pager that could be produced in its automated factory in Boynton Beach, Florida, within 72 minutes from the time an order was placed by computer from any Motorola sales office. Pagers could be ordered with various options and could be custom-built for individual customers (see Figure 1).

Within four years, Six Sigma had saved the company $2.2 billion. Motorola's Six Sigma architects had accomplished what most companies assumed was impossible. By 1993, Motorola was operating at nearly Six Sigma in many of its manufacturing operations. Within a short time, Six Sigma began to spread extensively to other industries and beyond manufacturing alone (Bandrowski & Madison, 2003c).

An organization that actively strives to build themes and practices of Six Sigma into its daily management activities, and shows significant improvements in process performance and customer satisfaction is considered to be a Six Sigma Organization

(Bandrowski & Madison, 2003b). Additionally, Six Sigma philosophy incorporates the following emphasis:

1. To qualify, you do not need to have achieved actual Six Sigma levels of performance (99.9997% perfect) on any process. Just taking all your processes to Four Sigma – 99.37% yield – would be an enormous achievement for any company.
2. However, only using Sigma measures or a few tools does not qualify a company to be a “Six Sigma Organization,” either. By definition, Six Sigma standards make the criteria tougher by demanding a whole new scope of activity and commitment.
3. You do not have to call it Six Sigma to be a Six Sigma organization.

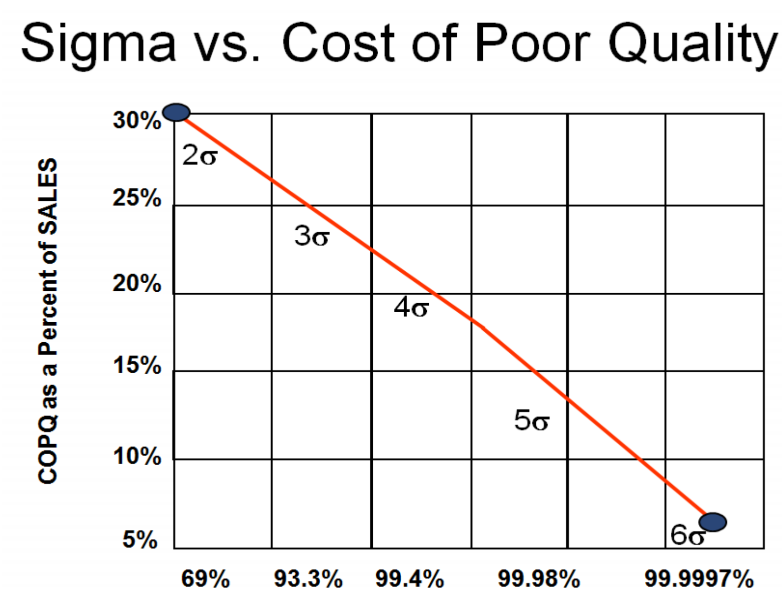


Figure 1: Six Sigma Levels vs. Cost of Poor Quality

Integration and Application of Lean Six Sigma Manufacturing Methodologies

In a study by Kaushik, Khanduja, Mittal, and Jaglan (2012), implications of applying Six Sigma methodology within small and medium enterprises (SMEs) were reviewed. The study was designed to yield valuable information to academics, consultants, researchers, and practitioners of Six Sigma methodologies. It provided documented evidence of a Six Sigma implementation project in a bicycle chain manufacturing unit which was a representative of a small- and medium-sized industry.

Sigma is a letter (σ) in the Greek alphabet representing standard deviation or the amount of variation within a given process (McAdam & Lafferty, 2004). According to Harry and Schroeder (2000), Six Sigma can be a powerful tool as a business strategy that enables companies to use simple and powerful statistical methods to achieve and sustain operational excellence. It is a business strategy that allows companies to drastically improve performance by designing and monitoring everyday activities in ways that will minimize waste of resources while increasing customer satisfaction (Snee, 2010).

Six Sigma has been implemented with success in many large corporations using the Six Sigma success factors model (see Figure 2). However, there is much less documented evidence of implementation of the methodology in smaller organizations (Harry & Crawford, 2004). As the importance of supply management issues grows in the global market, large firms are heavily dependent on small- to medium-sized enterprises to provide high-quality products and services at low cost. With this increasing demand for high-quality products and highly capable processes by large corporations, SMEs are left with no choice but to consider introducing the Six Sigma methodologies into their business models (Keller, 2003). Therefore, learners within AET programs are believed to have a much greater probability of working within the Six Sigma framework early and throughout their aviation/aerospace career trajectories.

Figure 2: Six Sigma Success Factors Model

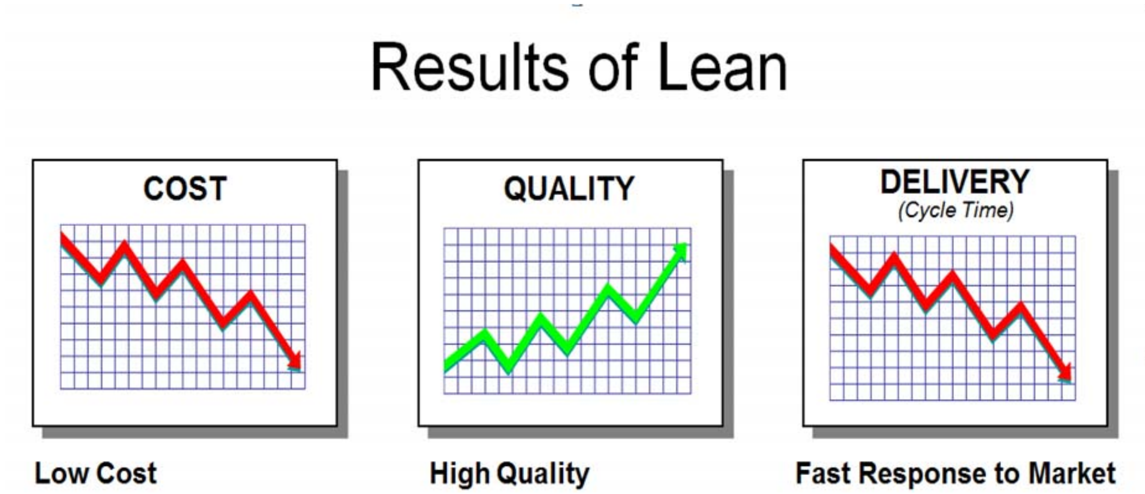
Since small companies are more agile, it is much easier to achieve buy-in support and commitment, as opposed to larger organizations with additional layers complicating the buy-in process. However, the education and training components present greater challenges for small companies. Moreover, small businesses do not have the luxury to release top talented people to engage in training followed by execution of the Six Sigma projects that are crucial to the day-to-day operations and problem-solving within the company. It is easier to link compensation to Six Sigma implementation in small businesses compared to a large corporation (Rowlands, 2004).

In a study conducted by Wessel and Burcher (2004), specific requirements for Six Sigma implementation were laid out for a sampling of SMEs in Germany. The study examined how Six Sigma had to be modified to be applicable and valuable in an SME environment. It was the first study to be conducted on a Six Sigma survey of SMEs.

Burton (2004) proposed alternative Six Sigma deployment models that would allow Small- or Medium- sized Enterprises (SME) to implement Six Sigma at a pace that would enable them to understand the methodologies and achieve benefits, without significant resource commitment and overhead structure of the traditional Six Sigma. As a result, SMEs are sometimes able to achieve faster and more effective benefits than their larger customers (Fiore, 2005). Additionally, Burton recommended an eight-step methodology for successful deployment of Six Sigma within SMEs. The eight steps to implementation include: (1) develop a Six Sigma strategy and overarching infrastructure, (2) complete an implementation plan, (3) team formation and education plan must begin concurrently, (4) company executives complete the Champion education to learn the Six Sigma process, methodology and tools, (5) selected individuals complete Green Belt certification, (6) other team members complete Yellow Belt certification, (7) later in the lifecycle, individuals are transitioned to the next level of Six Sigma achievement, and (8) in all cases, certification is accomplished by achievement, not attendance.

The key to success is once an owner of the business (in smaller firms) is convinced of the Six Sigma advantages and visualizes the benefits, it is much easier to implement the methodologies (Adams, Gupta, & Wilson, 2003). The initial focus of SMEs can be to reduce quality costs or waste in the system. Effort and investment, as well as results in smaller companies, are more visible within a short time. The study was conducted by an SME unit that manufactured bicycles in Haryana, India. The primary product of the manufacturing unit was the bicycle chain and the components required to create a bicycle chain (Adams, Gupta, & Wilson, 2003). For this problem, the Six Sigma DMAIC (Define, Measure, Analyze, Improve, and Control) methodology was utilized to examine the issue encountered during the manufacture of bicycle chain. During this study, there was an extremely high incidence of failure in raw materials used to manufacture the bicycle chain. By successfully implementing the DMAIC methodology, the SME was able to achieve an improvement from the existing sigma quality level of 1.40 σ to a much-improved sigma quality level of 5.46 σ (see Figure 3). For example, if the SMEs quality level was 2 σ, 69% of products and/or services would meet customer requirements with 308,538 defects per million opportunities. With a quality performance of 4 σ, 99.4% of the products and/or services would meet customer requirements and there would be 6,210 defects per million opportunities. As the quality performance level reaches 6 σ, 99.99966% of the products and/or services would meet customer requirements with just 3.4 failures per million opportunities, which is as close to flaw-free as a business can be.

- Examples of 3 Sigma Levels: 54,000 incorrect drug prescriptions per year, 5 crash landings per day at the busiest airports, and 54,000 lost pieces of mail per hour.
- Examples of 6 Sigma Levels: 1 incorrect prescription in 25 years, 1 crash landing in 10 years, and 35 lost pieces of mail per year.



- **Lower working capital**
- **Less scrap and rework**
- **Higher productivity**

- **Receive feedback at more frequent intervals**
- **Introduce design/quality improvements at a more rapid rate**

- **Shorter delivery time**
- **Faster to market with new products**
- **Improved market share**

Figure 3: Benefits of Lean Layout

The integration of lean manufacturing principles with technology includes potential impact it could have on organizational performance regarding quality, cost, and response time. The research was completed during a time of declining market share for U.S. automobile manufacturers which was caused by increased competition from the global automobile market. It was speculated that the integration of lean manufacturing principles with advances in technology would enable U.S. automobile manufacturers the ability to compete better on a global scale (Watson, 2006). This study used a mixed methodology of quantitative and qualitative methods to test the theory and acquire new knowledge while utilizing statistical methods to validate the results. A questionnaire was developed and used to determine the opinions of top executives and selected employees responsible for the implementation of lean manufacturing methodology and technological advancements. There were 28 technological advancements and a total of 15 lean manufacturing principles/initiatives identified as being utilized in the domestic automobile industry (Watson, 2006).

Lean manufacturing has historically been used by many organizations to compete on a global basis, and it is considered evolutionary in the process of continuous improvement in manufacturing concepts (Ohno, 1988; Womack & Jones, 1996; Womack, Jones, & Roos, 1990). The processes in which products were manufactured have included craft, mass production, and lean manufacturing. "Craft led to mass production, and mass production led to lean manufacturing." Lean manufacturing has revolutionized the way products are produced today. "Commonly known as the Toyota Production System (TPS)," lean manufacturing emerged out of necessity as a means for Japanese automobile manufacturers to compete, beginning with the Toyota Motor Company (Gunter, 1987; Ohno, 1988; Watson, 2006).

Henry Ford was credited with the invention of mass production, changing the way products were, and continue to be, produced in many industries. "These were paramount in advancing manufacturing concepts that led to world dominance in automobile manufacturing for domestic automobile manufacturers." In 1955, Ford, GM, and Chrysler accounted for 95% of all sales (Womack, Jones, & Roos, 1990; Watson, 2006). Henry Ford and Taiichi Ohno were pioneers in the improvement of manufacturing methods; Ohno is credited with the invention of the Toyota Production System. When comparing mass production against the lean manufacturing model, mass production requires more manufacturing space, more investment in tooling, and more development time. It results in more defects, higher costs, lower quality, and longer responses or lead times that result in reduced organizational performance (Hogg, 1993). Lean manufacturing and technological advances have provided organizations with a more efficient means to compete. These organizations must continually ask, "What is the impact of lean manufacturing principles integrated with technology on organizational performance in the way of quality, cost, and response time?" (Hogg, 1993; Watson, 2006). Several studies have been conducted on lean manufacturing principles and technology (Gagnon, 2004; Karlin, 2004; Mothersell, 2000; Olsen, 2004; Rasch, 1998; Shah, 2002; Starns, 1995). However, "none of the studies have focused on the impact of the integration of lean manufacturing principles with technology on organizational performance." (Watson, 2006)

A study conducted by Platzer and Harrison (2011) found that domestically owned automobile manufacturers worked diligently to compete with foreign-owned automobile manufacturers, yet their market share had shown a decrease over the years. The timing of the research was crucial to aid U.S automobile manufacturing proficiency. Several practitioners firmly believed in the importance of technology through enhancing manufacturing performance (Mathaisel & Comm, 2000).

With the increase in market share and improved performance of Asian automobile manufacturers, the determination was made that the subject warranted closer research. It seemed practical that benefits could be achieved by examining the relationship of the level of lean manufacturing principles integrated with technology and its effects on organizational performance (see Figure 4). The principles of lean manufacturing integrated with technology and the impact of quality, cost, and response time on organizational performance were compared. The study was conducted during a rather turbulent time in the U.S automobile market; therefore, the response rate was considered moderately low (Kumar, Antony, & Cho, 2009).

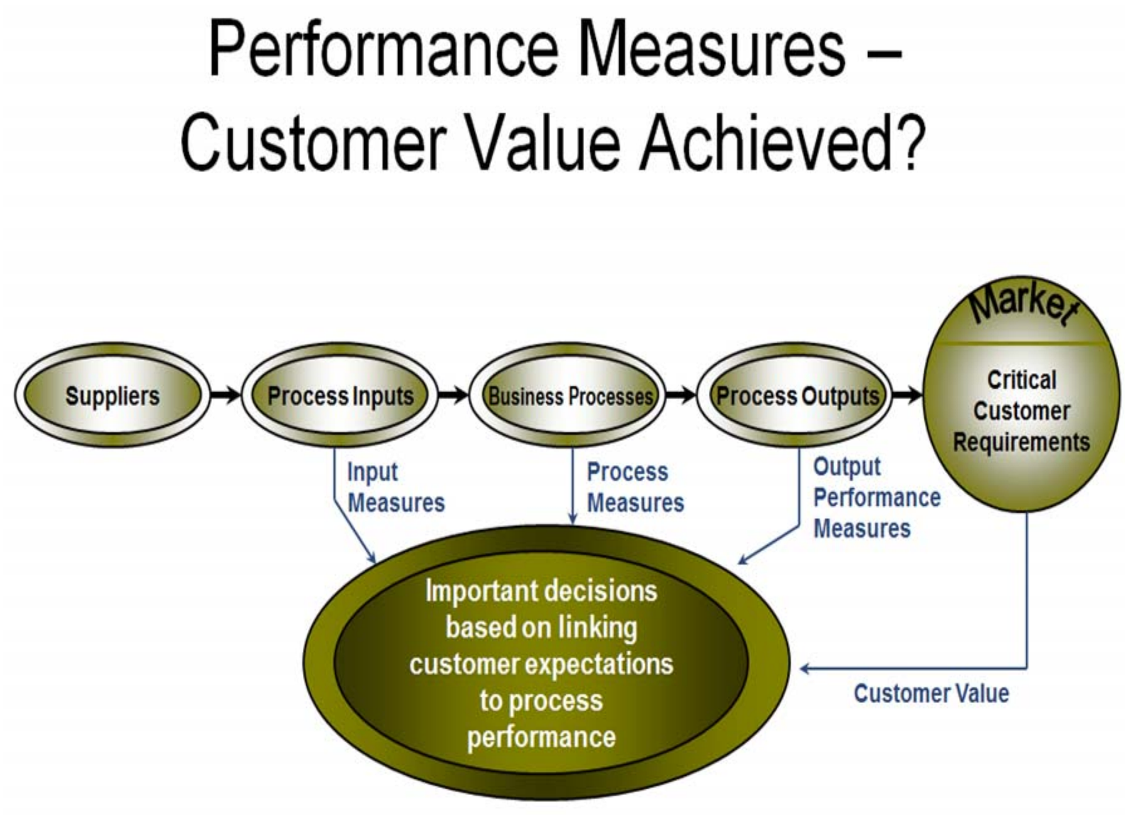


Figure 4: Six Sigma Performance Measures Model

Boumen's (2007) study regarding the "Integration and Test Plans for Complex Manufacturing Systems," is a compilation of the author's research papers with examples of practical applications. The research was performed as part of the Tangram research project in cooperation with the Embedded Systems Institute of the Eindhoven University of Technology and several other industry partners. He concluded that integration of automated test plans are often more efficient than manually created plans, which reduces the time-to-market of a complex system while maintaining the same final system quality.

Testing complex manufacturing systems, like lithographic machines, can involve as much as 45% of the total development time of a system. This testing can be reduced by choosing which test protocols must be performed in which sequence, without making investments in test cases or the system. By utilizing the test sequencing method developed by Boumen (2007), it is possible to make decisions that allow for a time, cost, and quality optimal test sequence to be constructed.

Development and construction of complex manufacturing systems are costly and time-consuming. Managing the product time-to-market is increasingly important and crucial to keeping these phases as short as possible while maintaining process and product quality (see Figure 5). Douglas and Conger (2007) described the methodology used to develop construction plans to integrate test methods and, moreover, the construction of optimal test plans.

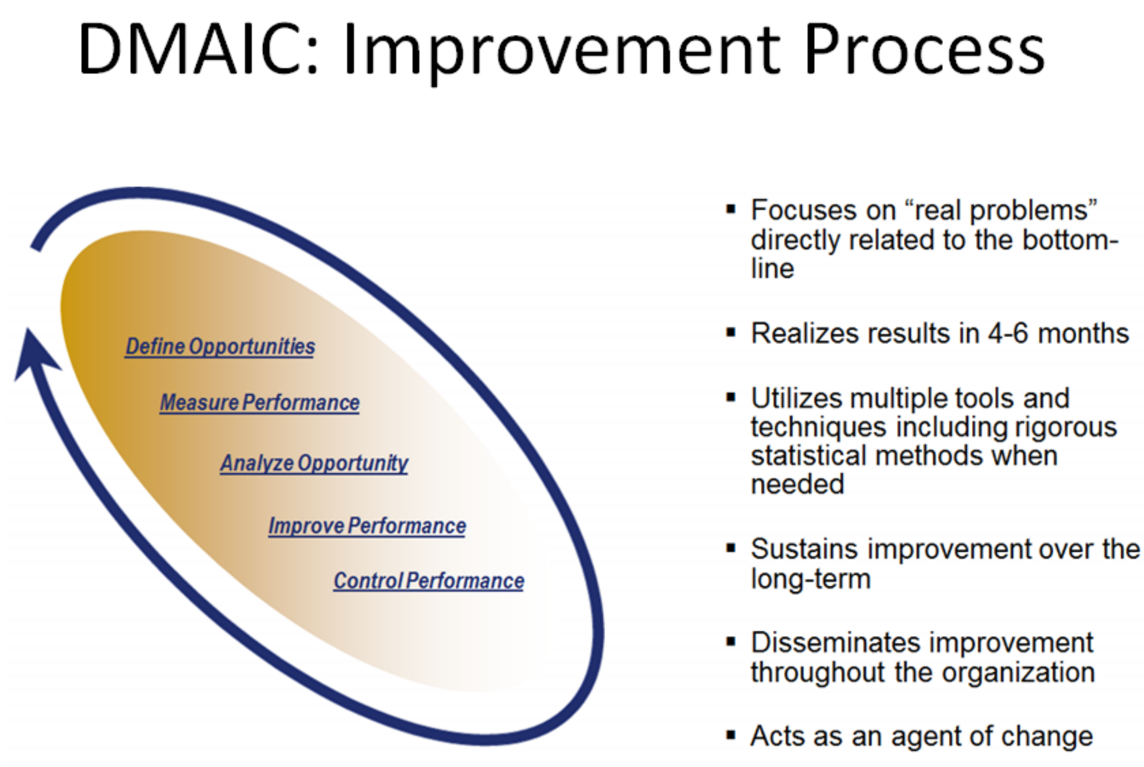


Figure 5: DMAIC Improvement Process Model

Testing complex manufacturing systems are expensive both in terms of time and money, as reported by Engel, Bogomolni, Shacher, and Grinman (2004). To reduce time-to-market of a new system or to reduce the lead time during the manufacturing of these systems, it is crucial to reduce the test time. Reducing test time can be accomplished by: (1) making testing faster by automation of test items, (2) making testing easier, by changing the system, and (3) doing testing smarter by choosing wisely which test cases to perform and in what sequence.

To achieve integration and test time reduction, three methods have been developed. The methods include: (1) construction of an optimal integration and test plan with respect to time, (2) cost, and (3) quality. The test program optimization method consisted of two steps and the first phase was the definition of a model of the test problem. The second phase consisted of calculating the optimal test plan based on the test model, given an objective function and possible constraints. By constructing a graph of the problem, all possible test sequences of the problem were obtained (Mothersell, 2000).

The integration plan optimization method consists of the same two steps as the test program optimization method. The integration model consists of modes with development times, interfaces that denoted system states represented by faults. This solution included a set of test sequences in which the test sequence depends on the outcome (pass/fail) of the previous tests (Emiliani, 2003).

The integration and test planning methods can be used to optimize real-life industrial integration and test plans. These plans may also be used for solving other problems. The results obtained from the project could be leveraged by providing an overview of challenges that may be solved using the methods developed (Emiliani, 2003). The research concluded that a successful integration method had been developed that created an optimal test plan. The method is based on sequential diagnosis methods from the literature and is adjusted to solve test planning problems for test phases. The study also concluded that a method had been developed that created an optimal integration plan. This particular method was based on assembly sequencing methods from the literature and is adjusted to solve integration planning problems. The conclusion was that a plan had been developed that created both an integration and test planning process. Several strategies could be used to combine integration and test plans. Practical extensions were introduced to solve real-life industrial problems. This study determined that there was also ample opportunity for continued research and development (Emiliani, 2003). The study recommended that further development and examination be focused on extending the current methods into the industry on a larger scale (Engel, Bogomolni, Shacher, & Grinman, 2004).

Economic Impact Related to Lean Six Sigma

General Electric's Jack Welch described Six Sigma as "the most important initiative GE has ever undertaken" (Bandrowski & Madison, 2003a). GE's operating income, a critical measure of business efficiency and profitability, hovered around the 10% level for decades. In 1995, Welch mandated that each GE operation, from credit card services to aircraft engine plants to NBC-TV, work together achieving Six Sigma. GE averaged about 3.5 sigma when it introduced the program. With Six Sigma embedding itself deeper into the organization's processes, GE achieved the previously "impossible" operating margin of 16.7% in 1998, up from 13.6% in 1995 when GE implemented Six Sigma focusing on the reduction of variation (see Figure 6). In dollar amounts, Six Sigma delivered more than $300 million to GE's 1997 operating income, and in 1998, the financial benefits of Six Sigma more than doubled to over $600 million (Bandrowski & Madison, 2003a).

Larry Bossidy, CEO of AlliedSignal, Inc., brought the $14.5 billion industrial giant back from the verge of bankruptcy by implementing the Six Sigma Breakthrough Strategy. Six Sigma initiatives allowed the operating margin in the first quarter of 1999 to grow to a record 14.1% from 12% one year earlier. Since Bossidy implemented the program in 1994, the cumulative impact of Six Sigma has been saving more than $2 billion in direct costs (Crom, 2010).

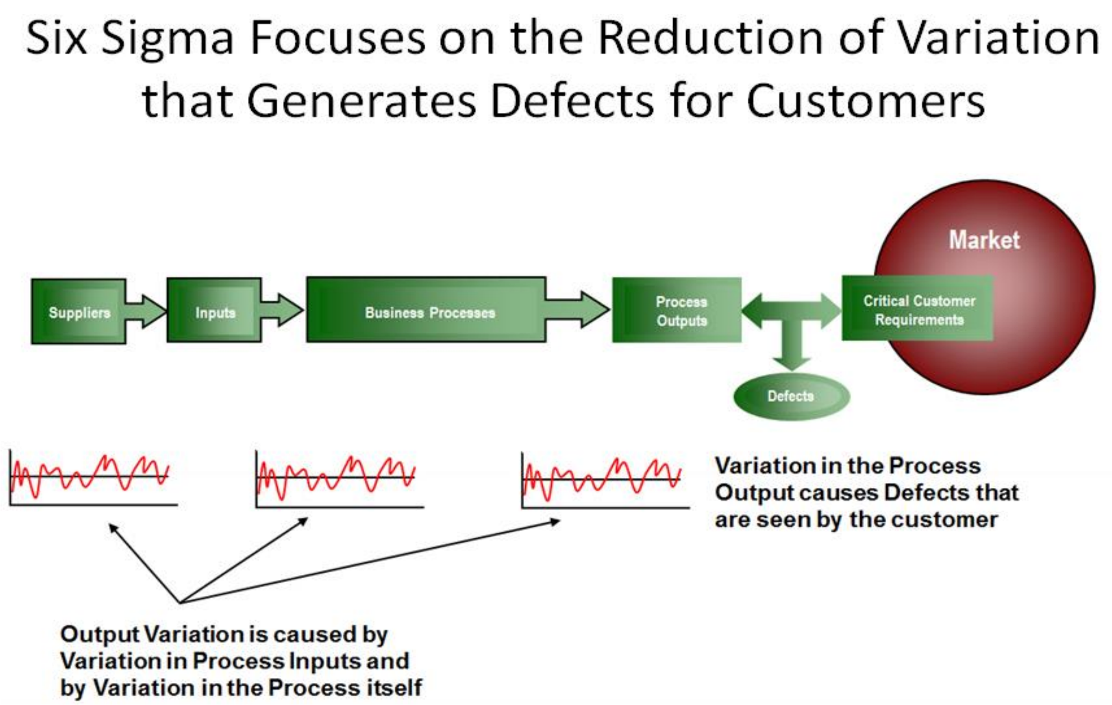


Figure 6: Six Sigma Reduction of Variation Model

Since taking over GE's industrial diamonds business in Worthington, Ohio, in 1994, William Woodburn increased the operation's return on investment fourfold and reduced the operation's costs in half by employing Six Sigma. He and his team have made their existing facilities so efficient that they have eliminated the need for new plants and equipment for at least another 10 years. Woodburn and GE's industrial diamond business exemplify how Six Sigma can enable a company to decrease costs, enhance productivity, and eliminate the need for new plant and equipment investments.

Polaroid Corporation's Joseph J. Kasabula believed that the most compelling reason companies embrace Six Sigma is its impact on the bottom line. Six Sigma is helping Polaroid to add 6 % to its bottom line each year. Asea Brown Boveri (ABB), which successfully applied Six Sigma to its power transformer facility in Munich, Indiana, has reduced measurement equipment error by 83%, piece count error from 8.3% to 1.3%, and no-load loss to within 2%. ABB also improved material handling, resulting in an annual estimated cost savings of $775,000 for a single process within a single plant (Bandrowski & Madison, 2003a).

As a consequence of several Six Sigma projects with the Six Sigma layout model, GE Capital's railcar leasing business achieved a 62% reduction in turnaround time at its repair shops, resulting in an enormous productivity gain for railroad and shipping customers (see Figure 7). As a result, the business is now two to three times faster than its closest rival. In addition to decreasing customer's costs, Green Belts have reduced border delays by 50% (Bandrowski & Madison, 2003a).

The core purpose for Home Depot is to “Improve Everything We Touch.” Every touch point whether with customers, associates, communities, suppliers, or shareholders is a turning point. Home Depot performs 1.3 billion transactions each year. At this scale, even if it operated with only a 1% error rate, the result would be an unacceptable level of mistakes. Establishing universal business processes and continuously striving to improve them is the only way to ensure that the core purpose is fulfilled (Womack & Jones, 2005).

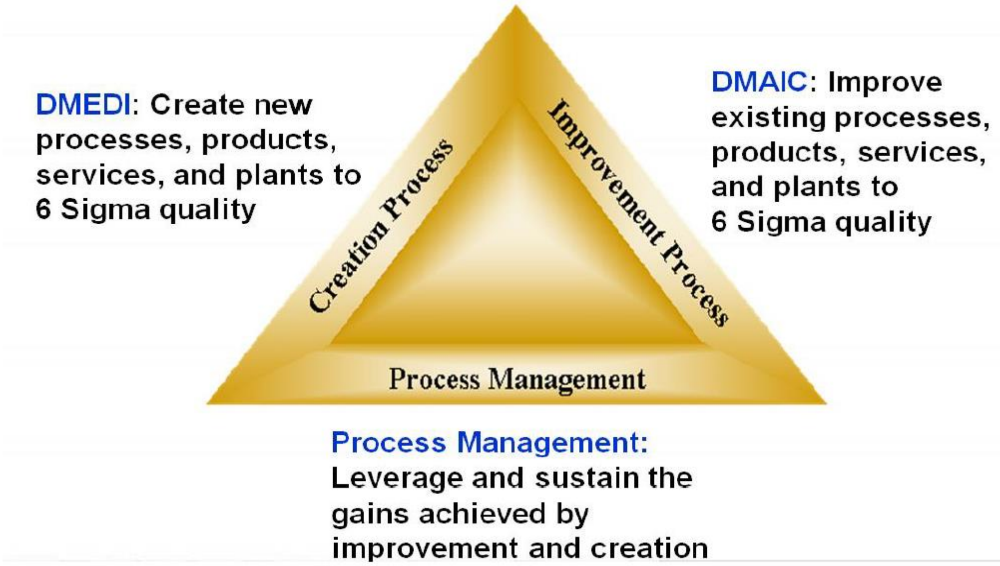


Figure 7: Six Sigma Layout Model

Six Sigma quality assurance methodology is employed to ensure acceptance and execution of business process improvement (BPI) at Home Depot. This disciplined, data-driven approach to eliminating procedural defects allows them to examine processes to identify core issues and components that will make or break their BPI efforts. Quality always begins and ends with the customer; Six Sigma is accustomed to ensure that they have sustainable processes in place to deliver what their customers need and expect (Womack & Jones, 2005).

Before employing Six Sigma, an organization must create a framework for cultural change. Until it is understood what drives people's perceptions, beliefs, and actions, changes will only be sustainable by accident. Many leaders underestimate the power of what has been referred to as the "soft stuff" and instead only focus on "hard stuff" like return on investment (ROI). To enable cultural change, executives must embrace essential "soft skills," where you understand that even the most technical of solutions will be implemented by people (Womack & Jones, 1996).

Assuming one has embraced soft skills and created a change-friendly framework, the next step is actually to perform BPI through Six Sigma. Home Depot directs Six Sigma via a steering committee composed of the executive leadership team headed by the chairperson, president, and CEO. The steering committee provides deployment direction, authorizes budgets, and provides general support. The Vice President of Business Process Improvement oversees deployment strategy, coaching, project tracking, and coordination. Other functional departments include internal communication, information technology (IT), human relations (HR), and strategic financial analysis (Lopez, 2005).

On the execution side, a pyramid of Six Sigma experts has been created, headed by seven "master black belts" who have each achieved command of a particular area of Six Sigma. Under the master black belts are layers of black belts, green belts, orange belts, and champions who hold varying levels of expertise and ensure the day-to-day enactment of Six Sigma methodology throughout the organization (Harry, Mann, & De Hodgins, 2010).

Following Six Sigma methodologies, everything addressed is based on a process or series of processes. For example, the customer shopping experience is broken down into a flow of events that include the availability of parking, carts, products, associates, registers, and loading assistance, as well as the accuracy of the transactional ring-up. If every process in the flow is performed at a 95% accuracy rate, the rolled throughput yield is only 69.8%. This means a customer would only have a 70% chance of a flawless shopping experience, proving that even at high execution levels, customer service delivery is a difficult journey that requires total commitment (Harry, Mann, & De Hodgins, 2010).

To provide a customer experience of the highest possible quality, there must be an understanding and measurement of customer "critical to quality" (CTQ) factors such as overall shopping experience, store atmosphere, in-stock levels and associate helpfulness from every point of view (Sower, Savoie, & Renick, 1999). By analyzing CTQs and comparing them to sales conversions, it can be determined what percentage of customers receive a defect-free shopping experience. Additionally, ways can be discovered to boost the percentage as close to 100 percent as possible (Lopez, 2005).

Leveraging technology to identify trends and provide timely analysis is a critical factor for success. Information Technology integration helps to perform Six Sigma-based BPI at the desired speed of execution. Systems governing business components such as labor, intranet, forecasting, and project management, as well as different platforms, must all be tightly integrated and freely share data for Six Sigma to be truly successful. Measuring progress every step of the way is the foundation of maintaining a focused, disciplined approach. Home Depot accomplishes this by driving expectations and measuring accountability with "project tollgates" that include three- and six- month rollout reviews and audits of project financials (Lopez, 2005).

What types of process improvement does Six Sigma actually enable? Home Depot has launched numerous successful BPI projects based on Six Sigma methodology. For example, on the logistics side they were able to save millions of dollars in the supply chain by reducing less-than-truckload (LTL) shipments to improve truck utilization. Additionally, they discovered through customer feedback that vacuum cleaners were placed out of reach on the display shelf, prohibiting shoppers from seeing, feeling, or using the product prior to purchase. By shelving vacuum cleaners at floor level, sales were improved. At the point of purchase, analysis of loss patterns revealed that by implementing wireless scan guns for cashiers, the errors were significantly reduced and customer flow-through was quicker (Lopez, 2005).

Rather than allowing companies to solve the same problems over and over again, Six Sigma enables an organization to eliminate problems once and for all, while maximizing shareholder value (see Figure 8). It creates a process mindset that breaks down complex situations to manageable sizes and trains new leaders to ensure that corporate goals are met. In such an environment, BPI becomes inevitable rather than achievable; all critical requirements from the customer to the boardroom can only benefit from allowing them to become turning points (Womack & Jones, 2005).

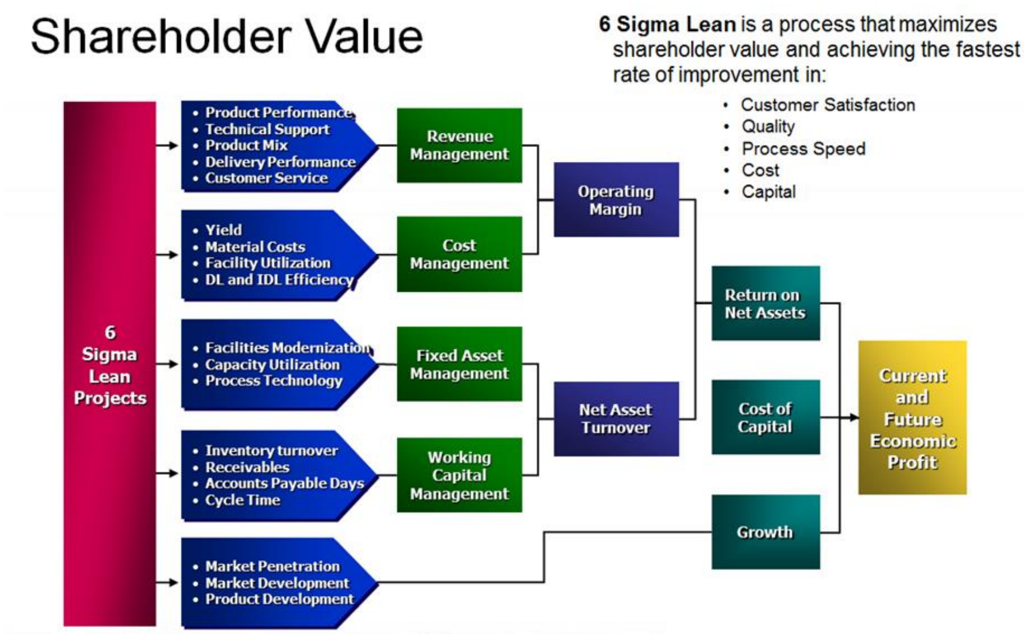


Figure 8: Maximizing Shareholder Value Chart

Summary

The literature review included a historical perspective on the origins of Lean Six Sigma and related methodologies in manufacturing. The findings regarding successful implementation strategies, an examination of the barriers to implementation of Lean Six Sigma, and Lean Six Sigma methodologies were discussed. The primary principle of Lean Six Sigma is the focus on activities critical to quality that offer the greatest opportunity to improve cost, quality, capital, and lead time (Truby, 2000). It was revealed that Lean Six Sigma methodologies could be a very powerful tool for tackling process inefficiency problems in advanced manufacturing industries including a variety of aviation and aerospace operations. However, this powerful methodology has not yet been widely adopted by many universities and colleges due to the misconception that it is only intended for manufacturing companies. Not only are colleges and universities failing to adopt Lean Six Sigma methodologies into business processes, but few are also providing courses or in-depth curriculum and practice in Lean Six Sigma.

The question that emerges is, why implement Six Sigma into the AET curriculum? The key objective in using Six Sigma goal model in many companies is to execute game winning strategies and drive shareholder and customer value (see Figure 9). As indicated by the majority of the findings, financial performance will be improved from the implementation of Lean Six Sigma methodologies. Other benefits gained from implementation of Lean Six Sigma are an improved work environment, active workforce involvement in the business, knowledge makes you more valuable, personal learning and advancement, improved work culture and job satisfaction, and cohesive, participative, and self-directed teams (Caterpillar Inc., 2000).

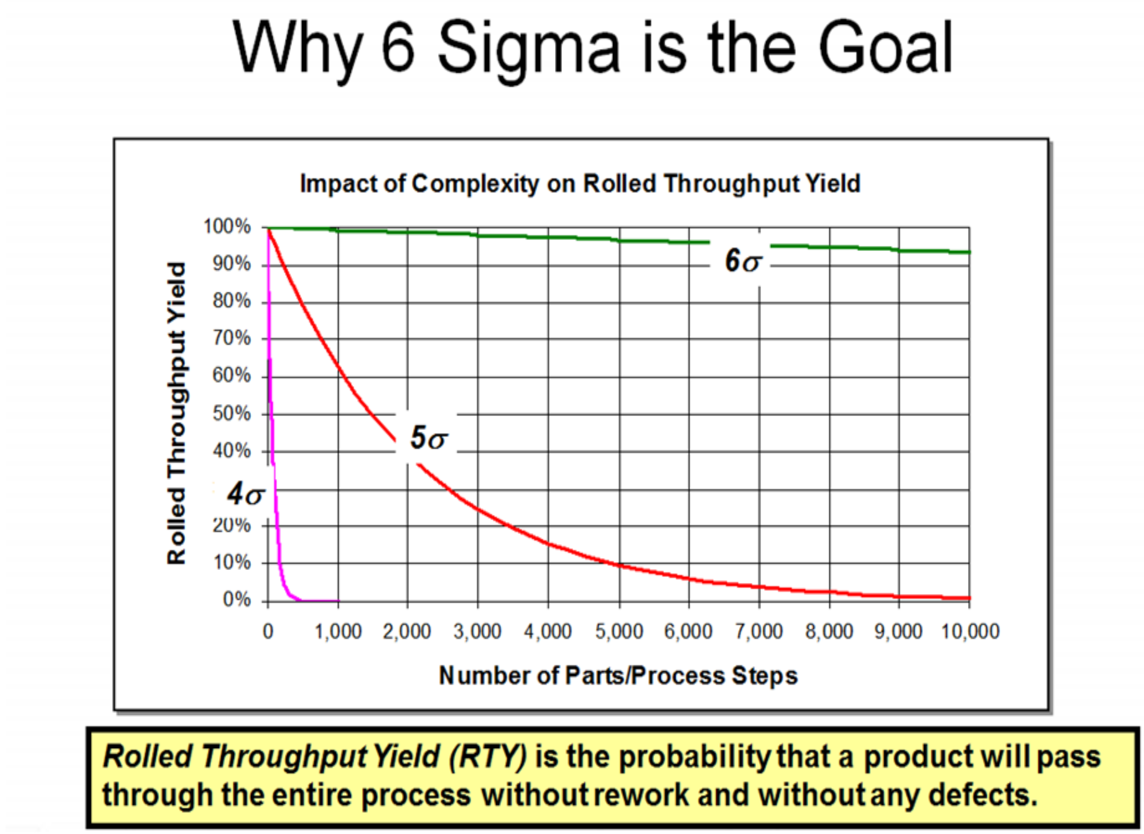


Figure 9: Six Sigma Goal Model

It is evident that there is considerable information supporting Lean Six Sigma methodologies and revealing the value proposition when its tools are wielded correctly. A tremendous opportunity exists to leverage the benefits of Lean Six Sigma methodologies to evaluate and develop relevant courses for AET programs and students. This will enable students to become capable day-one employees. Additionally, it will also serve the industry in addressing the efficiency and effectiveness demands of 21st-century global business models within which they operate.

CHAPTER 3: METHODOLOGY

Rationale

The purpose of this study was to develop and evaluate Lean Six Sigma advanced manufacturing methodologies as a course tailored to the training and education needs of students in an AET program and students within other technology manufacturing disciplines. The final outcome was to develop an Aeronautical Engineering Technology course that provides students opportunities to learn and implement advanced manufacturing techniques that are utilized in the aviation industry.

Feedback from update and benchmark meetings with SATT's Aviation Industry Advisory Board indicated that a gap surrounding Six Sigma practices existed among AET students that could be addressed through additional training, thereby, improving manufacturing and process competencies demanded by modern aviation manufacturing and operational environments. This study can benefit the AET curriculum and complement existing coursework, exposing students to modern manufacturing philosophies. It is a capstone of the student experience with a practical application of manufacturing techniques. The methodology, population and sample, methods for sampling, description of the survey, data analysis, and discussion of reliability and validity for the study are components of the evaluation of the course curriculum. The research methodology is described along with the rationale for its selection. The methodologies used for this study included a Pre-test/Post-test assessment of student knowledge levels and a course evaluation survey. The Pre-test assessment was used to determine student knowledge before participating in the Lean Six Sigma advanced manufacturing course. After completion of the course, students were administered the Post-test assessment to evaluate their knowledge level after participating in the curriculum. The Pre-test and Post-test were then compared to assess whether student understanding and knowledge levels of Lean Six Sigma had increased. The evaluation survey was administered to the students at the conclusion of instruction to evaluate student perceptions of the course.

Upon successful completion of the advanced aviation manufacturing curriculum, students should possess the necessary knowledge and expertise to perform as effective leaders and problem solvers in an advanced manufacturing environment. The objectives of the curriculum include: (1) demonstrate competencies to utilize advanced manufacturing processes required to operate a manufacturing facility, (2) utilize advanced process quality planning methods to implement a quality program into a manufacturing facility, (3) acquire knowledge and experience to implement supply chain management techniques to implement a logistic program into a manufacturing facility, and (4) attain knowledge of effective continuous improvement processes that will be utilized effectively and promoted throughout the program.

Theoretical Framework

The overall goal of this study was to develop a theoretical approach for implementing a Lean Six Sigma advanced manufacturing research methodologies course into Aeronautical Engineering Technology curriculum. The theoretical concept was defined as the integration of various industrial work ideas that are traditional regarding structure and theories, derived from synergizing different views to create a theoretical approach. By creating a new approach, the focus was on generating a functional premise on which to base the implementation of a Lean Six Sigma advanced manufacturing research methodologies course into the AET curriculum. The course has practical and project-based learning objectives as well as theory-based illustrations. The foundation for building the functional premise was constructed upon review of the seminal and empirical literature. Further, feedback was received from stakeholders as to what they deemed beneficial and value-added for the AET students enrolled in the course.

There was a perceived need for further research in the area of development and evaluation of Lean Six Sigma advanced manufacturing techniques in the AET course curriculum, based on the viewpoint of participants and the ideas and thoughts of those currently engaged in the environment and affected by the change. The points illustrated encompassed the main focus areas of Lean Six Sigma advanced manufacturing methodologies.

The plan of study requirements were assessed to ensure the appropriateness of developing and evaluating a Lean Six Sigma advanced manufacturing course for integration into the curriculum. Assessment, psychometric analysis, and survey methods were utilized. The assessment employed a Pre-test to attain a baseline knowledge level of students prior to exposure to the course. The students were then given the Post-test at the completion of the course presentation. The Pre-test and Post-test scores were analyzed using SPSS statistical software. As part of the course validation process, the Pre-test/Post-test instrument was examined using psychometric information collected to estimate internal consistency reliability, validity, item discrimination, and difficulty index (Carmines & Zeller, 1979; Cronbach, 1990; Guilford, 1954; Nunnally & Bernstein, 1994). The final method of analysis was a course evaluation survey administered to the

AET students who participated in the Lean Six Sigma advanced manufacturing course. The survey collected systematic and empirical data from the subjects. Descriptive statistics about the perceptions of the Lean Six Sigma advanced manufacturing methodologies course were estimated and interpreted.

As a project-based learning laboratory, this study provided students with the opportunity to perform in an educational environment that was very similar to an industrial working environment. The projects for the course were developed from the required outcomes of the SATT for the ABET-ETAC accredited plan of study and included:

1. Technical expertise in engineering materials, statics, strength of materials, applied aerodynamics, applied propulsion, and either electrical power or electronics.
2. Technical expertise having added depth in a minimum of three subject areas chosen from: manufacturing processes, vehicle design and modification, engineering materials, electro-mechanical devices and controls, industrial operations, and systems engineering including the appreciation of the engineering design cycle and the system life cycle relating to the manufacture and maintenance of aeronautical/aerospace vehicles and their components.
3. Ability to function effectively as a member or leader of a technical team.
4. Ability to apply written, oral, and graphical communication in both technical and nontechnical environments, and capacity to identify and use appropriate technical literature.
5. Understanding of and a commitment to addressing professional and ethical responsibilities including respect for diversity.
6. A commitment to quality, timeliness, and continuous improvement.

Population and Sample

The population for this study consisted of students enrolled in the Aeronautical Engineering Technology (AET) major in the School of Aviation and Transportation Technology at a large midwestern university. The total enrollment for the AET major during the study was between 225 and 259 students. The population was selected because the AET students were using the laboratory space in the School of Aviation and Transportation Technology to perform practical hands-on projects related to their aviation major. The subjects for the study consisted of all 28 students who were enrolled in the Lean Six Sigma Advanced Manufacturing course. The AET plan of study requires students to receive instruction in logistics, quality, and manufacturing terms and descriptions. The students are required to utilize the information learned and some of the basic lean manufacturing/continuous improvement philosophies to complete a senior capstone project. The plan exposed students to a manufacturing facility that closely resembled an operation that they could be hired to manage. Part of this plan allowed for organizing the powerplant lab space into more of a manufacturing cell, enabling learners to explore developing and operating a manufacturing facility. Courses were offered concurrently with gas turbine technical coursework. Students in the manufacturing course developed and implemented manufacturing simulations. Students in the turbine classes received education and training on the engines, while the Lean Six Sigma advanced manufacturing students managed the operation from the process development perspective. The study allows for the development of a world-class facility to train and educate future aviation manufacturing professionals. This facility is capable of teaching not only aviation students, but also advanced manufacturing students from any venue.

Instrumentation

Two instruments were developed and utilized in this study. The first was the Pre-test/Post-test assessment tool (see Appendix A). The assessment tool had been developed and pilot-tested for two semesters prior to use in this study. It was used to compare the before and after course results. The subjects were administered a 50 item multiple-choice Pre-test prior to exposure to the Lean Six Sigma advanced manufacturing course materials. The data from the assessment of the Pre-test/Post-test was used to estimate the reliability and validity of the instrument. The psychometric information included reliability, validity, item discrimination, and item difficulty (Carmines & Zeller, 1979; Cronbach, 1990; Guilford, 1954; Nunnally & Bernstein, 1994). The Pre-test internal consistency reliability estimate was Cronbach's Coefficient Alpha of .984, and the Post-test internal consistency reliability rating estimate was Cronbach's Coefficient Alpha of .978. Reliability provides an indication of the precision of measurement of a uniform construct, and the extent to which a subject's score reflects random measurement error. Measurement errors may be caused by: (1) examinee-specific factors such as motivation, concentration, fatigue, boredom, momentary lapses in memory, carelessness in marking answers, and lucky guesses, (2) test-specific factors such as specific questions selected for a test, ambiguous or tricky items, and poor directions, and (3) scoring-specific factors such as non-uniform scoring guidelines, carelessness, and counting or computational errors. An unreliable test offers no advantage over randomly assigning test scores to students. Therefore, it is desirable to use tests that demonstrate good reliability to ensure the test scores reflect more than random error (Wells & Wollack, 2003). Additionally, reliability is a prerequisite to test validity. If test scores cannot be assigned consistently, it is virtually impossible to conclude that the scores measure accurately. Validity refers to the extent to which inferences are made from a test are justified and accurate. Accordingly, adequate validity and reliability estimates are essential for useful assessment instruments and procedures (Wells & Wollack, 2003). An acceptable reliability estimate for new instruments is a Cronbach's Coefficient Alpha ≥ .70. It is generally considered unusual for validity coefficients to rise above .60 (Carmines & Zeller, 1979; Cronbach, 1990; Guilford, 1954; Nunnally & Bernstein, 1994). Additionally, a correlation calculation was performed using the assessment scores from the Pre-test and the Post-test to assess the validity of the test instrument. The validity coefficient of .46 was considered adequate. Validity is a function of the item difficulty of a test and defines how well a test measures what it was designed to measure.

The item discrimination index (D) measures the extent to which a test item discriminates or differentiates between students who do well on the overall test and those who do not do well on the overall test. There are three types of discrimination indexes: (1) positive discrimination index, persons who did well on the overall test chose the correct answer for a particular item more often than those who did poorly on the overall test; (2) negative discrimination index, persons who did poorly on the overall test chose the correct answer for a particular item more often than those who did well on the overall test, and (3) zero discrimination index, persons who did well and those who did poorly on the overall test chose the correct answer for a particular item with equal frequency. The item discrimination analysis of the test instrument had a range that remained positive for all 50 test items ranging from .18 to .27. Therefore, test items demonstrated a positive discrimination.

The item difficulty index indicates the proportion of students who answered the item correctly. The difficulty index (p) for the Pre-test given to the students at the beginning of the semester yielded a range from .18 to 1.00, with an overall average of .62 and indicates that the test items were "moderately difficult." The difficulty index (p) for the Post-test of the 50 items had a range from .47 to 1.00 and an overall average of .69. This range indicated a high proportion of students selected the correct response; the assessment items were categorized as "relatively easy" for this test administration. This result, therefore, may be expected since the students had received instruction regarding course content along with engaging in practical lab activities using the methodologies throughout the semester (Carmines & Zeller, 1979; Cronbach, 1990; Guilford, 1954; Nunnally & Bernstein, 1994). The instrument was determined to have an adequate degree of content and face validity and internal consistency reliability. Therefore, it was used to assess prior knowledge of the Lean Six Sigma tools and to tailor the course objectives to student needs.

After completion of the course, the subjects were again administered the Post-test to assess their knowledge level of the Lean Six Sigma tools after receiving instruction and engaging in hands-on project-based learning objectives. Comparative analysis using a paired samples *t*-test and Analysis of Covariance (ANCOVA) (Howell, 2006; Miller & Chapman, 2001; Rutherford, 2000) test were conducted to assess knowledge levels and report the results. The results of the Pre-test/Post-test analysis indicated that the instrument would be acceptable for the study.

The Aeronautical Engineering Technology Lean Six Sigma Course Evaluation Survey was developed to assess the perceptions of AET students after completion of the Lean Six Sigma course (see Appendix B). The design of the survey was critical to the success of the research. The survey used a Likert-type scale using five options. The survey consisted of two sections: Part A and Part B. The introduction provided students a letter of permission to conduct the research (see Appendix C). Part A of the survey requested demographic information from participants including grade level, gender, age, and program of study (see Table 1).

Table 1:

Student Demographics Part A

Q1. Your Class	Senior	16
	Junior	12
	Sophomore	0
	Freshman	0
	Total	28
Q2. Gender	Male	26
	Female	2
Q3. Age	18 – 21	20
	22 – 25	8
	26 – 29	0
Q4. Program of Study	AET - 28	28
	PFT - 0	0
	AMT - 0	0

*AET – Aeronautical Engineering Technology, PFT – Professional Flight Technology, and AMT – Aviation Management Technology

Part B of the survey asked the subjects their perceptions regarding the role of Lean Six Sigma advanced manufacturing methodologies. The items in Part B were derived from a synthesis of the literature that focused on the integration of Lean Six Sigma advanced manufacturing techniques. The survey included Likert-type scale items on a five-point scale: Strongly Disagree (SD) = 1, Disagree (D) = 2, Neither Agree or Disagree (NAD) = 3, Agree (A) = 4, and Strongly Agree (SA) = 5 (see Table 2). Once the three instruments were formatted for use, and IRB approval obtained, data collection began.

The survey items were selected based on how well student expectations would be reported and analyzed. The internal consistency reliability estimate for the survey yielded a Cronbach's Coefficient Alpha of .827 and a validity coefficient of .49. Based on previous research studies (Carmines & Zeller, 1979; Cronbach, 1990; Guilford, 1954; Nunnally & Bernstein, 1994), an acceptable reliability level is ≥ .70. The instrument was considered to have an adequate degree of reliability and validity for the study.

Table 2:

Survey Questions Part B

SQ1. The amount of work required for this course was appropriate.
SQ2. My level of course participation was appropriate.
SQ3. My knowledge of Lean Six Sigma methodologies has increased from this course.
SQ4. The course had clearly defined objectives.
SQ5. Course assignments supported the course objectives.
SQ6. Course required readings were relevant.
SQ7. The amount of writing was well-suited for the course.
SQ8. I received appropriate and timely feedback during the course.
SQ9. The course met your expectations.
SQ10. This course will be beneficial for career opportunities.
SQ11. My instructor provides clear explanations to questions.

Table Continued:

SQ12.	Your instructor used effective teaching methods for the course.
SQ13.	Your instructor was enthusiastic about the course.
SQ14.	The course met as scheduled.
SQ15.	Course assignments were interesting and stimulating.

Data Collection

Prior to data collection, approval was requested to conduct human subject's research from the Institutional Review Board (IRB). After approval was granted, the data collection procedures consisted of a purpose statement, a letter of permission to conduct research for the students (see Appendix C), and an informed consent form (see Appendix D) that was distributed to those students enrolled in the AET students in the Lean Six Sigma advanced manufacturing course. The data for this study were collected during the 2015 academic year from the AT490 Lean Six Sigma advanced manufacturing class.

This study consisted of a repeated measures method (Nunnally & Bernstein, 1994). A written Pre-test was used prior to participation in the Lean Six Sigma advanced manufacturing course objectives with a follow-up Post-test of written knowledge items following completion of the course topics (see Appendix E). The design and format of the written assessment instrument consisted of multiple-choice type items. The format was paper and pencil, but could be easily be adapted to computer-based online testing. Psychometric information was generated from the Pre-test/Post-test instrument to assess the reliability, validity, item discrimination, and difficulty index.

For the second analysis, the survey was distributed to the Aeronautical Engineering Technology Lean Six Sigma course subjects. Students were asked to sign a survey participation letter. Initially, paper copies of the survey were distributed to collect the completed surveys on the same day. As the study advanced, the survey was electronically distributed to the subjects and data were collected utilizing Qualtrics electronic software. Both groups (paper and electronic) have been included in the analysis of the survey data.

To ensure a high return rate, streamline the process, and avoid missing survey data, follow-up phone calls and emails were used during the data collection process. Respondents were reminded to respond to the survey by emails and phone calls prior to data collection. The target return rate was at least 60% in each sample group since this was considered an acceptable return rate based on previous studies (Carmines & Zeller, 1979; Cronbach, 1990; Guilford, 1954; Nunnally & Bernstein, 1994). 100% of the surveys were returned. The data were coded for analysis and entered into SPSS statistical analysis software.

Data Analysis

The data collected for the Pre-test/Post-test were analyzed with SPSS software. Descriptive statistics and two types of significant statistical tests were conducted on the Pre-test/Post-test data; paired samples *t*-test and an Analysis of Covariance (ANCOVA) (Howell, 2006; Miller & Chapman, 2001; Rutherford, 2000). A paired samples *t*-test was used to compare differences between the Pre-test and Post-test scores of the participants. Analysis of covariance (ANCOVA) was also utilized (Winer, Brown, & Michels, 1991) for posthoc analyses. This type of methodology allowed for comparison analysis of various categories. The analysis was conducted by grade, gender, and race/ethnicity. The decision criterion utilized was based on a 95% confidence interval with a level of significance of $p < .05$. The means of two groups were also examined to determine if there were any significant differences ($p < .05$) between the groups.

The final data analysis utilized a locally developed survey. Part A of the Aeronautical Engineering Technology Lean Six Sigma course survey gathered demographic information from participants including grade level, gender, age, and program of study; frequencies were reported. These data described the overall characteristics of the subjects and the population.

Part B of the survey used descriptive statistics. The data collected from the surveys were analyzed with SPSS software to provide percentages, means, and standard deviations related to each survey item. The internal consistency reliability (Cronbach's Coefficient Alpha), means, and standard deviations for the Likert-scale items were reported. The decision criterion utilized for the survey analysis was based on a 95% confidence interval with a level of significance of $p < .05$. Survey response frequency data were analyzed and interpreted.

CHAPTER 4: FINDINGS

The purpose of this study was to develop and evaluate Lean Six Sigma advanced manufacturing methodologies for the Bachelor of Science degree program in the AET curriculum. It also intended to develop an industry standards course based on the education of future aviation manufacturing professionals. This chapter presents the findings from the Pre-test/Post-test assessment and the survey data. The findings are organized and presented around the research questions posited for this study.

Research Question #1: *Did the knowledge level of AET students increase following exposure to Lean Six Sigma and completion of the advanced manufacturing methodologies course?*

The Pre-test/Post-test assessment was utilized to answer research question #1. The analysis examined the effects of the Lean Six Sigma advanced manufacturing methodologies course intervention (changes between the Pre-test and Post-test scores) on students' knowledge level. A paired sample *t*-test was used for the analysis of before and after results, since it allowed for comparison of two sample means, which in this study consisted of the Pre-test and Post-test data. The purpose of the test was to determine whether there was statistical evidence that the sample mean difference between the paired observations on a particular outcome was significantly different from zero. The paired samples *t*-test is a parametric test. Since the acceptable level of normality for kurtosis and skewness was approximately -1 to 1, the data for the Pre-test and Post-test are considered normally distributed. Also, the Shapiro-Wilk test for normality was nonsignificant for both the Pre-test and Post-test scores (Kachigan, 1991; Privitera, 2015). It was believed that students would have a higher knowledge level of Lean Six Sigma methodologies after receiving instruction. Students showed a difference in knowledge between the Pre-test and Post-test administration. The paired samples *t*-test, $t(27) = 4.90$, $p < 0.001$, revealed a mean score difference between the Pre-test and Post-test scores of 8.07 with a standard deviation of 8.72 and a standard error mean (SEM) of 1.65. The data indicated that students' Post-test scores ($M = 69.71$, $SD = 7.88$, and SEM = 1.49) were significantly increased from the Pre-test scores ($M = 61.64$, $SD = 7.70$, and SEM = 1.46) (Kachigan, 1991; Privitera, 2015). The paired samples *t*-test analysis revealed that students, reflected by the effect size of their scores, were significantly different in their knowledge of Lean Six Sigma methodologies after receiving the course instruction. The SPSS Pre-test/Post-test descriptive statistics paired samples *t*-test results are included in Table 3.

Table 3

Pre-test/Post-test Descriptive Statistics Paired Samples t-test

Pair 1	Mean	N	Std. Deviation	Std. Error Mean
Pre-test	61.64	28	7.70	1.46
Post-test	69.71	28	7.88	1.49

Pre-test/Post-test Paired Samples t-test

				95% CI of the Diff				
Pair 1	Mean	SD	SEM	Lower	Upper	t	df	Sig. (2-tailed)
Pre-test/Post-test	8.07	8.72	1.65	11.45	4.69	4.90	27	.001

Table Continued:

Pre-test/Post-test Descriptive Statistics

Pre-test			Statistic	Std. Error
	Mean		61.64	1.46
	95% Confidence	Lower Bound	58.66	
	Interval for Mean	Upper Bound	64.63	
	5% Trimmed Mean		61.70	
	Median		60.00	
	Variance		59.28	
	Std. Deviation		7.70	
	Minimum		44	
	Maximum		76	
	Range		32	
	Interquartile Range		11	
	Skewness		.06	.44
	Kurtosis		-.13	.86

Post-test			Statistic	Std. Error
	Mean		69.71	1.49
	95% Confidence	Lower Bound	66.66	
	Interval for Mean	Upper Bound	72.77	
	5% Trimmed Mean		69.52	
	Median		70.00	
	Variance		62.14	
	Std. Deviation		7.88	
	Minimum		54	
	Maximum		90	
	Range		36	
	Interquartile Range		13	
	Skewness		.31	.44
	Kurtosis		.26	.86

Table Continued:

Pre-test/Post-test Paired Samples Correlations

Pair 1	N	Correlation	Sig.
Pre-test/Post-test	28	.37	.05

Analysis of Covariance (ANCOVA) was used because it can view a combination of multiple regression and analysis of variance. The simplest form of ANCOVA is when there is one categorical (grouping) variable and one quantitative (predictor) variable, called the covariate (Field, 2013). ANCOVA has the same assumptions as any linear model except that there are two important additional considerations: (1) independence of the covariate and treatment effect, and (2) homogeneity of regression slopes (Field, 2013). When ANCOVA is conducted, the overall relationship between the outcome (dependent variable) and the covariate are examined. An additional ad-hoc analysis for research question #1 was conducted with ANCOVA to examine three different variables for the effects of intervention (gender, grade, and race/ethnicity) to check for significant or non-significant differences between variables. The testing was reduced from three to two variables that included grade and race/ethnicity due to the small number of females participating in the study.

First, underlying data assumptions for ANCOVA (i.e., no interaction between treatment and covariance) were examined. The assumption of ANCOVA held true that no significant interaction effect existed between Pre-test and race/ethnicity (p = .12) or between Pre-test and grade level (p = .19). The homogeneity of variance assumption assumes that all groups have the same or similar variance. It utilizes the F-statistic, which is a robust assumption, as long as group sizes are equal (Field, 2013; Jamieson, 2004; Privitera, 2015). The results of Levene's test indicated that the homogeneity of variance assumption was met for both grade levels (*F = .23, p > .05)* and race/ethnicity groups (F = .18, *p* > .05).

Using ANCOVA, the second analysis consisted of the analysis of Pre-test and Post-test data as it related to grade level. The findings indicated that student knowledge did not reveal a significant difference based on the student's grade level, *B = 4.04* (t_{25} = -1.35, *p* = .19), (See Table 4). The SPSS estimated marginal means analysis by grade level is presented in Table 5 and reflects the grade level adjusted for the Pre-test and Post-test covariate.

Table 4

Pre-test/Post-test Descriptive Statistics by Grade Level

Dependent Variable: Pre-test

Grade Level	Mean	Std. Deviation	N
Junior	58.50	8.66	12
Senior	64.00	6.15	16
Total	61.64	7.70	28

Dependent Variable: Post-test

Grade Level	Mean	Std. Deviation	N
Junior	66.50	6.94	12
Senior	72.13	7.88	16
Total	69.71	7.88	28

Levene's Test of Equality of Error Variances

Dependent Variable: Post-test

F	*df1*	*df2*	*Sig.*
.23	1	26	.63

Table Continued:

Regression

	B	Std. Error	Beta	t	Sig.
Constant	49.66	11.69		4.25	.001
Pretest	.29	.20	.28	1.47	.16
Grade Level	4.04	3.00	.26	1.35	.19

Table 5

Pre-test/Post-test Estimated Marginal Means by Grade Level

Dependent Variable: Pre-test

			95% Confidence Interval	
Grade Level	Mean	Std. Error	Lower Bound	Upper Bound
Junior	59.38[a]	2.15	54.95	63.82
Senior	63.34[a]	1.85	59.53	67.14

a. Covariates appearing in the model are evaluated at the following values: Post-test = 69.71.

Dependent Variable: Post-test

			95% Confidence Interval	
Grade Level	Mean	Std. Error	Lower Bound	Upper Bound
Junior	67.41[a]	2.21	62.86	71.95
Senior	71.45[a]	1.89	67.55	75.34

a. Covariates appearing in the model are evaluated at the following values: Pre-test = 61.64.

Using ANCOVA for the third analysis consisted of the examination of the Pre-test and Post-test data as related to race/ethnicity. Table 6 presents the ANCOVA analysis by race/ethnicity, $B = -5.07$ ($t_{25} = -1.61$, $p = .12$), and Table 7 presents the SPSS estimated marginal means analysis by race/ethnicity and reflects race/ethnicity adjusted for the Pre-test and Post-test covariate. It was revealed that student knowledge did not demonstrate a significant change based on the student's race/ethnicity. In summary, there was no significant difference between grade level and race/ethnicity after Pre-test scores were controlled for Post-test results.

Table 6

Pre-test/Post-test Descriptive Statistics by Race/Ethnicity

Dependent Variable: Pre-test

Race/Ethnicity	Mean	Std. Deviation	N
White, non-Hispanic	63.58	6.59	19
Other	57.56	8.65	9
Total	61.64	7.70	28

Dependent Variable: Post-test

Race/Ethnicity	Mean	Std. Deviation	N
White, non-Hispanic	69.05	7.49	19
Other	71.11	8.95	9
Total	69.71	7.88	28

Levene's Test of Equality of Error Variances

Dependent Variable: Post-test

F	*df1*	*df2*	*Sig.*
.18	1	28	.67

Regression

Coefficients

	B	Std. Error	Beta	t	Sig.
Constant	42.36	11.47		3.69	.001
Pretest	.50	.20	.49	2.57	.02
Race	-5.07	3.00	-.31	-1.61	.12

Table 7

Pre-test/Post-test Estimated Marginal Means by Race/Ethnicity

Dependent Variable: Pre-test

Race/Ethnicity	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
White, non-Hispanic	63.85[a]	1.52	60.73	66.99
Other	56.97	2.21	52.41	61.53

a. Covariates appearing in the model are evaluated at the following values: Post-test = 69.71.

Dependent Variable: Post-test

Race/Ethnicity	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
White, non-Hispanic	68,08[a]	1.70	64.58	71.59
Other	73.15[a]	2.54	67.92	78.38

a. Covariates appearing in the model are evaluated at the following values: Pre-test = 61.64.

Research Question #2: *Did the course meet the AET students' expectations following participation in the Lean Six Sigma advanced manufacturing course?*

The final analysis used a course evaluation survey to answer research question #2. The Aeronautical Engineering Technology Lean Six Sigma course survey yielded an internal consistency reliability estimate (Cronbach's Coefficient Alpha) of .83 for 15 items and 28 participants (see Table 8). An alpha between .70 and .80 was considered adequate for newly developed instruments and basic research (Carmines & Zeller, 1979; Cronbach, 1990; Guilford, 1954; Nunnally & Bernstein, 1994).

The decision criterion utilized for this study was means of > 3 (i.e., neutral or above) for the survey responses and descriptive statistics for each item were reported in

Table 8. The results from the student responses, therefore, indicated that expectations for the course were met. Table 9 presents the survey response frequencies.

Table 8

Internal Consistency Reliability Estimate for the Survey

Cronbach's Coefficient Alpha = .83	N of Items = 15

Student Demographics Part A

Q1. Your Class	Senior	16
	Junior	12
	Sophomore	0
	Freshman	0
	Total	28
Q2. Gender	Male	26
	Female	2
Q3. Age	18 – 21	20
	22 – 25	8
	26 – 29	0
Q4. Program of Study	AET - 28	28
	PFT - 0	0
	AMT - 0	0

*AET – Aeronautical Engineering Technology, PFT – Professional Flight Technology, and AMT – Aviation Management Technology

Survey Descriptive Statistics Part B

				Std.	Std.	95% C.I. for Mean	
		N	Mean	Dev.	Error	Lower	Upper
SQ1. The amount of work required for this course was appropriate.	Junior	6	4.50	.55	.22	3.93	5.08
	Senior	22	4.32	.48	.10	4.11	4.53
	Total	28	4.36	.49	.09	4.17	4.55

Table Continued:

SQ2. My level of course participation was appropriate.	Junior	6	4.17	.41	.17	3.74	4.60
	Senior	22	4.45	.51	.11	4.23	4.68
	Total	28	4.39	.50	.09	4.20	4.59
SQ3. My knowledge of Lean Six Sigma methodologies has increased from this course.	Junior	6	4.17	.41	.17	3.74	4.60
	Senior	22	4.27	.46	.10	4.07	4.47
	Total	28	4.25	.44	.08	4.08	4.42
SQ4. The course had clearly defined objectives.	Junior	6	4.33	.52	.21	3.79	4.88
	Senior	22	4.32	.48	.10	4.11	4.53
	Total	28	4.32	.48	.09	4.14	4.51
SQ5. Course assignments supported the course objectives.	Junior	6	4.33	.52	.21	3.79	4.88
	Senior	22	4.36	.49	.11	4.15	4.58
	Total	28	4.36	.49	.09	4.17	4.55
SQ6. Course required readings were relevant.	Junior	6	4.50	.55	.22	3.93	5.07
	Senior	22	4.41	.50	.11	4.19	4.63
	Total	28	4.43	.50	.10	4.23	4.62
SQ7. The amount of writing was well-suited for the course.	Junior	6	4.33	.52	.21	3.79	4.88
	Senior	22	4.18	.40	.08	4.01	4.36
	Total	28	4.21	.42	.08	4.05	4.38
SQ8. I received appropriate and timely feedback during the course.	Junior	6	4.50	.55	.22	3.93	5.07
	Senior	22	4.36	.58	.124	4.11	4.62
	Total	28	4.39	.57	.11	4.17	4.61
SQ9. The course met your expectations.	Junior	6	4.33	.52	.21	3.79	4.88
	Senior	22	4.36	.49	.11	4.15	4.58
	Total	28	4.36	.49	.09	4.17	4.55
SQ10. This course will be beneficial to career opportunities.	Junior	6	4.17	.41	.17	3.74	4.60
	Senior	22	4.41	.50	.11	4.19	4.63
	Total	28	4.36	.49	.09	4.17	4.55
SQ11. My instructor provides clear explanations to questions.	Junior	6	4.33	.52	.21	3.79	4.88
	Senior	22	4.45	.51	.11	4.23	4.68
	Total	28	4.43	.50	.10	4.23	4.62
SQ12. Your instructor used effective teaching methods for the course.	Junior	6	4.33	.52	.21	3.79	4.88
	Senior	22	4.45	.51	.11	4.23	4.68
	Total	28	4.43	.50	.10	4.23	4.62

Table Continued:

		N	Mean	Std. Dev.	Std. Error	95% C.I. for Mean Lower	Upper
SQ13. Your instructor was enthusiastic about the course.	Junior	6	4.50	.55	.22	3.93	5.07
	Senior	22	4.64	.49	.11	4.42	4.85
	Total	28	4.61	.50	.09	4.41	4.80
SQ14. The course met as scheduled.	Junior	6	4.67	.52	.21	4.12	5.21
	Senior	22	4.73	.46	.10	4.53	4.93
	Total	28	4.71	.46	.09	4.54	4.89
SQ15. Course assignments were interesting and stimulating.	Junior	6	4.17	.41	.17	3.74	4.60
	Senior	22	4.50	.51	.11	4.27	4.73
	Total	28	4.43	.50	.10	4.23	4.62

Table 9

Survey Response Frequencies

	*SD**	*S**	*N**	*A**	*SA**
SQ1. The amount of work required for this course was appropriate.	0	0	0	18(64%)	10(36%)
SQ2. My level of course participation was appropriate.	0	0	0	17(61%)	11(39%)
SQ3. My knowledge of Lean Six Sigma methodologies has increased from this course.	0	0	0	21(75%)	7(25%)
SQ4. The course had clearly defined objectives.	0	0	0	19(68%)	9(32%)
SQ5. Course assignments supported the course objectives.	0	0	0	18(64%)	10(36%)
SQ6. Course required readings were relevant.	0	0	0	16(57%)	12(43%)

Table Continued:

SQ7. The amount of writing was well-suited for the course.	0	0	0	22(79%)	6(21%)
SQ8. I received appropriate and timely feedback during the course.	0	0	1(3%)	15(54%)	12(43%)
SQ9. The course met your expectations.	0	0	0	18(64%)	10(36%)
SQ10. This course will be beneficial for career opportunities.	0	0	0	18(64%)	10(36%)
SQ11. My instructor provides clear explanations to questions.	0	0	0	16(57%)	12(43%)
SQ12. Your instructor used effective teaching methods for the course.	0	0	0	16(57%)	12(43%)
SQ13. Your instructor was enthusiastic about the course.	0	0	0	11(39%)	17(61%)
SQ14. The course met as scheduled.	0	0	0	8(29%)	20(71%)
SQ15. Course assignments were interesting and stimulating.	0	0	0	16(57%)	12(43%)

*SD – Strongly Disagree, D – Disagree, N – Neutral, A – Agree, and SA – Strongly Agree

In summary, this chapter examined the data collected from the Pre-test and Post-test assessments that were administered to students prior to and after receiving instruction. The data showed that the Pre-test and Post-test instrument possessed an adequate degree of reliability and validity. The findings indicated that students had increased their knowledge in Lean Six Sigma advanced manufacturing methodologies.

However, there were no significant differences between the two groups by grade level and race/ethnicity. Additionally, the course evaluation survey revealed that students reported a high degree of satisfaction with the course.

CHAPTER 5: CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

This purpose of this study was to develop and evaluate a Lean Six Sigma advanced manufacturing methodologies course for the AET curriculum. The objectives for this course included: (1) AET students will develop the competencies required to effectively utilize advanced manufacturing processes to successfully operate a manufacturing facility, (2) AET students will acquire the knowledge and skills required to effectively utilize advanced process quality planning methods to successfully implement a quality program in a manufacturing facility, (3) AET students will increase their knowledge and experiences to successfully implement supply chain management techniques and logistic programs in a manufacturing facility, and (4) AET students will promote and implement a continuous improvement process that will be successfully utilized throughout the curriculum. Accordingly, the research questions posited for this study included:

1. Did the knowledge level of AET students increase following exposure to Lean Six Sigma and completion of the advanced manufacturing methodologies course?
2. Did the course meet the AET students' expectations following participation in the Lean Six Sigma advanced manufacturing course?

This study served as a development platform for courses in the AET program. Additional dissemination will occur through presentations at teacher education and advanced manufacturing conferences, regionally and nationally, and through articles published in peer-reviewed journals.

Conclusions

Students had been using the lab space in the School of Aviation and Transportation Technology (SATT) to engage in practical hands-on projects related to their aviation major. This study developed the Lean Six Sigma advanced manufacturing course to allow undergraduate AET students to receive instruction in logistics, quality, and manufacturing terms and descriptions. Students received instruction in the Lean Six Sigma tools and utilized their new knowledge of basic lean manufacturing and continuous improvement philosophies to complete course projects. The course projects included transforming the School's powerplant laboratory into a more typical aerospace manufacturing cell layout, therefore, enabling the exploration of ways to operate an advanced manufacturing facility based on modern industry standards and practices. Students in this advanced aviation manufacturing course developed and implemented manufacturing simulations to test process improvement techniques. The vision for this study was to develop a world class course utilizing an operating laboratory facility to better educate and equip students as future aviation manufacturing professionals with industry-leading skill sets. This study provided the required data for development and evaluation of a Lean Six Sigma advanced manufacturing course. In addition, the course has been engineered to be used for future scaffolding opportunities with other SATT courses, which in turn could provide a robust and salient minor for the AET curriculum in advanced aviation manufacturing.

The development and evaluation of a Lean Six Sigma advanced manufacturing methodologies course for the Aeronautical Engineering Technology curriculum became the focus of this study after reviewing plan of study requirements and assessing the appropriateness of developing and evaluating a Lean Six Sigma advanced manufacturing course in the Aeronautical Engineering Technology curriculum.

The research was conducted using quasi-experimental and survey methods. The study employed a Pre-test and Post-test to obtain a baseline of the knowledge level of students prior to exposure to the course. The students were given the Post-test after the course presentation, and the scores were analyzed using SPSS statistical software.

The assessment data gathered from the Pre-test/Post-test was used to determine the reliability and validity of the instrument. Reliability, validity, item discrimination, and item difficulty were examined. The Pre-test reliability estimate was .984, and the Post-test reliability estimate was .978. Validity for the test instrument was calculated using a correlation calculation based on the Pre-test and Post-test scores. The validity coefficient was r = .46 which indicated that the test instrument possessed moderate validity.

The item discrimination analysis for the test instrument had a range that remained positive for all 50 test items. The difficulty index (p) for the Pre-test indicated a "moderately" difficult level; however, the Post-test difficulty index result was in the "easy" range indicating a high proportion of students selected the correct response. This result was not unexpected considering the students had instruction with the curriculum and were engaged with project-based practical lab objectives using the methodologies throughout the semester (Carmines & Zeller, 1979; Cronbach, 1990; Guilford, 1954; Nunnally & Bernstein, 1994).

The Pre-test/Post-test assessment was utilized to answer research question #1. The analysis reviewed the effects of the intervention (changes between Pre-test and Post-test scores). The paired sample *t*-test allowed for comparison of two population means that consisted of the Pre-test and Post-test. The acceptable level of normality for kurtosis and skewness was close to zero; it was considered to be a normal distribution (Kachigan, 1991; Privitera, 2015).

The central theme of this study was the belief that students would have a higher knowledge level of Lean Six Sigma methodologies after receiving instruction. To satisfactorily answer the research questions, three analyses were conducted. The results revealed that students' Post-test scores did significantly improve from the Pre-test scores. The paired samples *t*-test analysis revealed that student scores showed significant change (positively) in the knowledge of Lean Six Sigma methodologies after receiving course instruction. Student knowledge level increased after exposure to Lean Six Sigma and completion of the advanced manufacturing methodologies course.

Due to small sampling size for gender, the ANCOVA analysis was reduced from three categories (gender, grade, and race/ethnicity) to two categories that included only grade level and race/ethnicity due to the small number of female subjects. There was no significant difference between grade level and race/ethnicity after Post-test scores were controlled for Pre-test results.

ANCOVA was used to perform a secondary analysis for research question #1. The second and third analysis consisted of the Pre-test and Post-test data related to grade level and race/ethnicity. The results of this analysis revealed that student knowledge did not show a significant change based on grade level or race/ethnicity. An increase in student knowledge based on exposure to the Lean Six Sigma methodology material was confirmed.

The final analysis for research question #2 involved the Aeronautical Engineering Technology Lean Six Sigma course survey data. ANOVA was selected for this analysis because it is capable of identifying and measuring various sources of variation within data (Jamieson, 2004; Privitera, 2015). The decision criterion utilized for the survey analysis was based on a 95% confidence interval with a level of significance of $p < .05$. The Aeronautical Engineering Technology Lean Six Sigma course survey yielded a Cronbach's Coefficient Alpha of .83 for 15 items and 28 participants. An alpha between .70 and .80 was considered adequate for newly developed instruments and basic research (Carmines & Zeller, 1979; Cronbach, 1990; Guilford, 1954; Nunnally & Bernstein, 1994). Survey response frequency data were collected and interpreted using a mean of >3 (i.e., neutral or above) for the responses. The findings led to the conclusion that student expectations for the course were met. The course developed from this study can likely be incorporated into AET programs.

Implications

The study revealed several themes that could benefit students in preparing for careers in advanced aerospace manufacturing roles. As a project-based learning framework, this study allowed students the opportunity to perform in a learning facility and environment very similar to an industrial working environment. The projects for the course were developed from the required outcomes for the ABET-ETAC accredited plan of study in SATT. The objectives for this course included:

1. AET students will develop the competencies required to effectively utilize advanced manufacturing processes to successfully operate a manufacturing facility.

2. AET students will acquire the knowledge and skills required to effectively utilize advanced process quality planning methods to successfully implement a quality program in a manufacturing facility.
3. AET students will increase their knowledge and experiences to successfully implement supply chain management techniques and logistic programs in a manufacturing facility.
4. AET students will promote and implement a continuous improvement process that will be successfully utilized throughout the curriculum.

Due to semester time constraints, the objectives were not completely integrated into one course. The most significant accomplishment from this study was that students were prepared to take the Lean Six Sigma Green Belt certification test after successfully completing the course. Accordingly, there are several implications for additional development of this course and future research. Although this study revealed a benefit to receiving instruction in Lean Six Sigma methodologies, further inquiry should be conducted to determine if there is a potential benefit for students to learn additional advanced aviation manufacturing techniques and certifications. Another implication for research is the need to evaluate the benefits of Lean Six Sigma advanced manufacturing methodologies and implement those continuous improvement processes into academic institutions. The results gathered from the development and evaluation of the Lean Six Sigma advanced manufacturing methodologies course could be bench-marked and utilized to establish a new minor or possibly a graduate level plan of study.

In summary, students were presented with Lean Six Sigma advanced methodologies and were successful in modeling and completing project-based learning activities. This course has likely been beneficial for students who have graduated from the AET program. There is a need to continue development of the Lean Six Sigma advanced manufacturing course; it fits well with the requirements of Lean Six Sigma continuous improvement philosophies. Accordingly, continuous improvement tools may be utilized to enhance and transform the learning activities in several of the AET courses.

Recommendations

This study, as is the case with most studies, had several limitations. For example, the population for this study consisted of only those students enrolled in the Aeronautical Engineering Technology (AET) major in the School of Aviation and Transportation Technology at a large midwestern university. The total enrollment for the AET major during the study was 225 to 259 students. The subjects for the study consisted of 28 students and were determined by enrollment in the Lean Six Sigma advanced manufacturing course. It could have been beneficial to have a larger pool of subjects for the study. Additionally, there were some key improvements suggested that have already been integrated into the course. One is the class is no longer taught concurrently with another course. The original idea blended two courses and used them as a collaboration opportunity. However, it was observed that there was insufficient time to build the cohesiveness between the courses without causing both to fall behind in their respective objectives. The course was, therefore, developed into a stand-alone course with the lecture and team-building objectives taught during the first half of the semester. The project-based learning activities were emphasized during the second half of the semester. This enabled students to have the prerequisite knowledge of objectives before engaging in the more intensive project-based learning objectives. Accordingly, in light of the study's findings, conclusions, and limitations the following recommendations are offered for practice and future research:

1. During the initial stages of development of the Lean Six Sigma Advanced Manufacturing course, students were provided instruction in project management techniques. After two semesters, it was determined that students did not have the necessary abilities and knowledge to complete advanced project –based learning activities. Therefore, it is recommended that a project management course be developed that concentrates solely on project management. This would provide students an opportunity to apply knowledge, skills, tools, and techniques related to project activities to meet project requirements. This course would be presented as a prerequisite to the Lean Six Sigma advanced manufacturing course. The project management techniques learned from this course will better prepare students for the project-based learning activities that they would be expected to complete during the Lean Six Sigma advanced manufacturing course.
2. Develop graduate level courses for students to assist them to further specialize or focus on a particular concentration area within Lean Six Sigma methodologies. An advanced process quality planning course would be an example of a focused course. The graduate level experience would be tailored towards a student preparing for a Lean Six Sigma Blackbelt or Master Blackbelt certification.
3. Use the currently developed courses to offer a minor concentration in Lean Six Sigma advanced manufacturing methodologies. The courses would be organized for undergraduate students to complete without involving additional time before graduation.

4. Recruit industry partners to work with students on real-life problems from the field; provide a working laboratory for brainstorming ideas for integration and implementation into the facilities of industry partners.
5. Develop a powerplant laboratory within a technology incubator to grow and develop new techniques and processes. It could be a responsive research and development facility for industry partners to bring projects to the lab for testing.
6. Develop and evaluate a Project Management Professional (PMP) certification program. Using industry best practices, students could be provided the learning objectives and be evaluated with respect to the expected outcomes. The course should be a project-based learning curriculum allowing students practical project management exercises.
7. Identify key issues and trends in aviation and advanced manufacturing, develop and evaluate cutting-edge courses to foster increased technical competence, and provide students advanced skills as they enter the workforce.
8. Initiate an Advanced Process Quality Planning (APQP) course for innovation to advance student knowledge in aviation and manufacturing processes.
9. Leverage technology to establish a "Center of Excellence" for next generation product design, industrial analysis, and process development.
10. Research and develop a graduate level advanced program/project management course. The course could create advanced project planning and control techniques. Students would receive instruction in planning, organizing, directing, and controlling of company resources. The mode of delivery for the course should use project-based learning activities.
11. Future studies should include larger populations and samples of subjects while

controlling for variables of interest and significance.

12. Future studies should examine courses related to Lean Six Sigma advanced manufacturing methodologies programs and explore related achievement and affective outcome assessment instruments and procedures.

In summary, it is incumbent upon academic institutions to keep pace with the newest skill sets demanded by highly dynamic global technology industries like aviation and aerospace. The success of students, the most important customers in academic institutions and, therefore, the academic programs, depends on it. Doing so will prepare students to meet the challenges that lie ahead and equip them with the tools for life-long learning and careers in a global aerospace and advanced manufacturing environment.

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APPENDICES

APPENDICES

Appendix A

Lean Six Sigma Pre-test/Post-test

1. What does DMAIC stand for?

    a. Define, measure, analyze, inspect, control
    b. Define, measure, ask, inspect, control
    c. Determine, measure, analysis, improvement, convert
    d. Define, measure, analyze, improve, control

2. The Sigma quality level associated with Six Sigma is equivalent to what defect level (in parts per million)?

    a. 6210 ppm
    b. 223 ppm
    c. 3.4 ppm
    d. 5.1 ppm

3. Does CCR stand for complex customer requirements?

    a. True
    b. False

4. What does DMEDI stand for?

    a. Define, measure, explore, design, improve
    b. Define, measure, explore, develop, implement
    c. Define, measure, explore, develop, improve
    d. Derive, measure, explore, design, implement

5. Six Sigma is a business driven, multi-dimensional structured approach to ________.

    a. Increasing customer satisfaction
    b. Lowering defects
    c. Improving processes
    d. All of the above

6. ANALYZE phase includes ___________.

    a. Identify vital projects X's and statistically validate them
    b. Communicate & sign off to close project
    c. Generate potential solutions & assess failure modes
    d. All of the above

7. _____________ is a document that provides a framework and objective for an improvement project.

    a. Goal statement
    b. Business case
    c. Problem statement
    d. Project charter

8. A sample that will lead to incorrect conclusions about the population and which will not be representative of the population is.

    a. Clustered
    b. Biased
    c. Random
    d. Stratified random

9. If you were a Six Sigma Deployment Leader in the organization, what steps would you perform first?

    a. Develop a vision and mission for the organization and execute a Six Sigma Deployment plan in the organization.
    b. Perform statistical analysis in the process and identify root causes.
    c. Help process achieves its metrics by executing process improvement projects.
    d. Identify areas of best practices and guide green belts to execute them.

10. One of the key roles of a Champion (Sponsor) is___________________?

    a. Hire team of Master Black Belt, Black Belts, among others
    b. Develop process maps
    c. Perform statistical analysis
    d. Play a pivotal role in that they own the processes of the business and therefore, must ensure process improvements are captured and sustained

11. They set a very clear scope for all Six Sigma projects. They are responsible for approving any changes to the scope of the project.

    a. Six Sigma deployment leader
    b. Champion (Sponsor)
    c. Master Black Belt
    d. Black Belt

12. They are expert statisticians and help the Black Belts in the case of issues.

    a. Champion (Sponsor)
    b. Master Black Belt
    c. Black Belt
    d. Green Belt

13. This position drives more than one process improvement project within the functional area and achieves the savings and quality goals.

    a. Champion
    b. Master Black Belt
    c. Black Belt
    d. Green Belt

14. These are the project-specific, full or part-time resources that provide a process and cross-functional knowledge, as well as help sustain the gains.

    a. Yellow Belt
    b. Champion (Sponsor)
    c. Black Belt
    d. Green Belt

15. What is the purpose of a storyboard?

    a. To tell a story
    b. To give a detailed description of how the project is progressing
    c. To show all steps
    d. None of the above

16. How do customers communicate with us?

    a. Product returns
    b. Contract cancellations
    c. Change in market share
    d. All of the above

17. A CCR would include?

    a. Be measurable
    b. Establish a target
    c. Important to the customer
    d. All of the above

18. ________ means the process does not produce the same results every time the product or service is delivered.

    a. Out of control
    b. Variation
    c. Broken
    d. None of the above

19. A precise description of the specific criteria used for the developing measures, the methodology to collect the data, the person responsible for collecting the data describes what?

    a. Project charter
    b. Team role
    c. Operational definition
    d. Goal statement

20. What does DMADV stand for?

    a. Define, measure, analyze, develop, validate
    b. Define, measure, assess, design, verify
    c. Determine, measure, analyze, develop, validate
    d. Define, measure, analyze, design, verify

21. What is NOT included in the DEFINE stage of the DMAIC Process?

    a. Define the problem
    b. Document the team charter
    c. Identify CTQ's to measure
    d. Identify symptoms vs. causes

22. What do the 5 S's stand for when using this Lean tool for the Improve stage?

    a. Sort, stabilize, shine, standardize, sustain
    b. Sort, stack, sweep, stabilize, sustain
    c. Sweep, shine, standardize, sustain, succeed
    d. Sort, stabilize, scrub, standardize, sustain

23. Which one is NOT a correct statement about Six Sigma?

    a. Maximizing variation makes for consistency.
    b. 1979, Motorola used Six Sigma to improve product quality and business processes which eventually saved the company.
    c. GE adopted Six Sigma, drove profits from 10% to 17.7%, worth $300 million to the company in 1997.
    d. A disciplined method of using extremely rigorous data- gathering and statistical analysis to pinpoint sources of errors and ways of eliminating them.

24. Lean is__________?

    a. Identifying and eliminating wasteful steps in production processes and the office information flow processes.
    b. A systematic approach to reducing batch sizes by flowing the product or processes at the pull of the customer.
    c. A philosophy that seeks to minimize the working capital required to produce a product or provide a service. In other words, the value added time through a process should dramatically outweigh the non-value added time.
    d. All of the above

25. Lean Six Sigma is_______________?

    a. Application of the DMAIC methodology, supplemented with concepts extracted from the principals of lean. Combined, they provide a sustainable process for increasing velocity, managing inventory/capacity and reducing waste.
    b. Specifying a value from the customers' viewpoint.
    c. Driving to the "True Root Cause"
    d. All of the above

26. Which one is NOT one of the Laws of Lean Six Sigma?

    a. The Law of the Market
    b. The Law of Flexibility
    c. The Law of Velocity
    d. The Law of Diminishing Returns

27. Which one is NOT a benefit of Lean Six Sigma?

    a. Customer loyalty and retention
    b. Shorter customer leads time demands
    c. Downward price pressure- lower costs
    d. Higher investment capital

28. Which statement is KEY to the success of Lean Six Sigma?

    a. Top management carries the flag.
    b. It must be a culture where everyone in the company is contributing.
    c. Everyone's actions, questions, measurement systems, values, and focus drives the culture.
    d. All of the above

29. KPI stands for Key Performance Indicators?

    a. True
    b. False

30. Which statement is NOT one of the Lean Improvement Measures?

    a. People productivity
    b. Non-right first time
    c. Value added per person
    d. Delivery schedule adjustment dates

31. Waste is anything other than the minimum amount of equipment, materials, parts, space and people time, which is absolutely essential to add value to the product or service?

    a. True
    b. False

32. In Lean tools, which one is NOT one of removal of 7 wastes?

    a. Idle time
    b. Process
    c. Bad quality
    d. Supplier visits

33. A bar graph that displays the results of performance data is called?

    a. Histogram
    b. Run chart
    c. Box plot
    d. Bar chart

34. Control charts __________.

a. Help manage variation
b. Help monitor the process
c. Help teams discover root causes
d. All of the above

35. The basis for a Pareto chart is __________.

a. Determine root cause
b. 80/20 rule
c. Look at factors
d. None of the above

36. A problem statement __________.

a. Focuses on the pain
b. States effect
c. Measurable
d. All of the above

37. The DMAIC methodology should be used when a product or process is in existence at your company but is not meeting customer specification or is not performing adequately.

a. True
b. False

38. DMEDI entails application of creativity in using data to design new robust processes, products, and services. DMEDI aims at securing a quantum leap over existing processes, products or services and seeks a competitive advantage.

a. True
b. False

39. Part-time professional that participates on a Black Belt project team or leads smaller projects. Typically has two weeks of classroom training in methods and basic statistical tools.

a. Yellow Belt
b. Green Belt
c. Black Belt
d. Master Black Belt

40. Which is NOT one of the foundational elements of Lean Six Sigma?

   a. SPC
   b. QFD
   c. DOE
   d. ISO 9000

41. Which item is NOT included in the ANALYZE phase of DMAIC?

   a. Identify waste
   b. Kaizen
   c. Over producing
   d. Defects

42. Which DMAIC process appoints the team, the charter, picks resources, measurement tools and appoints a Champion?

   a. Define
   b. Measure
   c. Analyze
   d. Control

43. Which is part of a Team Charter?

   a. Defining what, why and when
   b. Problem statement, mission statement, stretch goals
   c. Boundaries, team members, project plan, support required
   d. All of the above

44. VOC stands for Voice of the Coordinator?

   a. True
   b. False

45. The SIPOC diagram is a high-level process map that includes___________.

   a. Suppliers, Inputs, Process, Outputs, Customers
   b. Suppliers, Instruments, Process, Outputs, Customers
   c. Suppliers, Inputs, Production, Outcome, Customers
   d. Suppliers, Instruments, Production, Outputs, Customer

46. QFD stands for Quality Function Development. QFD is a sophisticated tool to translate ‘voice of the customer’ requirements and competitor analysis into product and service features.

    a. True
    b. False

47. Sigma is the Greek letter representing a statistical unit of measure that defines the standard deviation of a population. It measures the variability or spread of the data.

    a. True
    b. False

48. Six Sigma is a measure of variability. It is a name given to indicate how much of the data fall within the customers’ requirements. The higher the process sigma, the more process outputs, products, and services meet customers’ requirements- or, the fewer the defects.

    a. True
    b. False

49. In what DMAIC stage do we interpret the measures, find a cause and effect relationship, determine process capability, determine cycle time or speed of the process and find true “Root Cause”?

    a. Define
    b. Measure
    c. Analyze
    d. Improve

50. One of the best ways to get to the root cause of the problem is to use the “Five-Why” Analysis? This is where you repeatedly ask “why” five times, or until you get to the root cause.

    a. True
    b. False

Appendix B

Lean Six Sigma Course Evaluation Survey

INSTRUCTIONS: Please read the following questions and choose the response that most closely reflects your perspective of the Lean Six Sigma advanced manufacturing course and instructor. Your responses will be completely anonymous, so please be honest in your responses.

1. The amount of work required for this course was appropriate.

- □ Strongly Agree
- □ Agree
- □ Undecided
- □ Disagree
- □ Strongly Disagree

2. My course participation was appropriate.

- □ Strongly Agree
- □ Agree
- □ Undecided
- □ Disagree
- □ Strongly Disagree

3. My knowledge of Lean Six Sigma methodologies has increased from this course.

- □ Strongly Agree
- □ Agree
- □ Undecided
- □ Disagree
- □ Strongly Disagree

4. The course had clearly defined objectives.

- □ Strongly Agree
- □ Agree
- □ Undecided
- □ Disagree
- □ Strongly Disagree

5. Course assignments supported the course objectives.

□ Strongly Agree
□ Agree
□ Undecided
□ Disagree
□ Strongly Disagree

6. Course required readings were relevant.

□ Strongly Agree
□ Agree
□ Undecided
□ Disagree
□ Strongly Disagree

7. The amount of writing was well-suited for the course.

□ Strongly Agree
□ Agree
□ Undecided
□ Disagree
□ Strongly Disagree

8. I received appropriate and timely feedback during the course.

□ Strongly Agree
□ Agree
□ Undecided
□ Disagree
□ Strongly Disagree

9. The course met your expectations.

□ Strongly Agree
□ Agree
□ Undecided
□ Disagree
□ Strongly Disagree

10. This course will be beneficial for career opportunities.

□ Strongly Agree
□ Agree
□ Undecided
□ Disagree
□ Strongly Disagree

11. My instructor provided clear explanations to questions.

□ Strongly Agree
□ Agree
□ Undecided
□ Disagree
□ Strongly Disagree

12. Your instructor used effective teaching methods for the course.

□ Strongly Agree
□ Agree
□ Undecided
□ Disagree
□ Strongly Disagree

13. Your instructor was enthusiastic about the course.

□ Strongly Agree
□ Agree
□ Undecided
□ Disagree
□ Strongly Disagree

14. The course met as scheduled.

□ Strongly Agree
□ Agree
□ Undecided
□ Disagree
□ Strongly Disagree

15. Course assignments were interesting and stimulating.

□ Strongly Agree
□ Agree
□ Undecided
□ Disagree
□ Strongly Disagree

Appendix C

Letter to Student

Dear Student,

I am requesting your participation in a brief course survey about the Lean Six Sigma advanced manufacturing course in the School of Aviation and Transportation Technology (SATT). As the instructor of the course, I would like to get more feedback about your experiences with this course. The survey is very brief and will only take approximately 5 minutes of your time to complete. Your input will help evaluate the effectiveness of the course and benefit you and future students in the SATT. Please complete the survey by [date]. Your participation in this survey is completely voluntary, and all of your responses will be kept confidential. No personally identifiable information will be associated with your responses. The Purdue University Institutional Review Board has approved this survey. Feedback from our students is imperative to us.

Thank you for your time and cooperation.

Respectfully,

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Appendix D

Purdue University Participant Consent Form

For participants at Purdue University:

RESEARCH PARTICIPANT CONSENT FORM

The Development and Evaluation of a Lean Six Sigma Advanced Manufacturing Methodologies Course for the Aeronautical Engineering Technology Curriculum

James Greenan, Ph.D.
Department of Curriculum and Instruction
Purdue University

Purpose of study: The purpose of this study was to develop and evaluate Lean Six Sigma advanced manufacturing methodologies for the Bachelor of Science in AET curriculum, utilizing a course tailored specifically towards training and education of future aviation manufacturing professionals.

What will participation involve?: You will also be asked to complete a Pre-test on Lean Six Sigma advanced manufacturing methodologies. You will receive instruction on the course objectives throughout the duration of the semester. At the completion of the semester, you will be asked to complete a Post-test over the Lean Six Sigma advanced manufacturing methodologies. The Pre-test and Post-test data will be used for comparison purposes along with a course evaluation survey. The course evaluation survey will consist of a questionnaire regarding your experiences during the course.

How long will I be in the study?: Each participant will be asked to enroll in the AT490 Lean Six Sigma Advanced Manufacturing course and participate for the duration of a semester. The course will be presented at the School of Aviation & Transportation Technology, at the Purdue University Airport.

What are the possible risks or discomforts?: With regard to your safety, the risk is minimal: no more risk exists than the amount encountered in everyday life.

Are there any potential benefits?: You may improve your employability skills by adding the knowledge gained from the course to your resume. You are also eligible to test for the American Society for Quality (ASQ) Green Belt certification. We hope that the benefits to society will be a greater understanding of Lean Six Sigma advanced manufacturing methodologies.

Will I receive payment or other incentive?: You will not receive monetary payment for your participation.

Will information about me and my participation be kept confidential?: All data collected from you will remain anonymous. To prevent any link between your identifying information and performance, all forms with your information will be kept in a separate file from the data collected. Identifying information will not be used in the data analysis or in any subsequent presentation or document. No other identifying information will be linked to the data, making all research data anonymous. All data will be stored in a locked cabinet and destroyed one year after the last participant has been tested. The research records of this project may be reviewed by principle investigators or coinvestigators involved in the management and administration of this study. Findings from this study may be published and presented in a scientific journal or conference. In addition, any departments responsible for regulatory and research oversight may also review records from this project.

What are my rights if I take part in this study?: Your participation in this study is voluntary. You may choose not to participate or, if you agree to participate, you can withdraw your participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Who can I contact if I have questions about the study?: For research-related problems or questions regarding your rights as a research participant, contact the Principal Investigator, Dr. James Greenan, Department of Curriculum and Instruction, Purdue University, at 765-494-7314 or jgreenan@purdue.edu. You may also contact the Purdue University Human Research Protection Program (HRPP), at (765) 494-5942.

Documentation of Informed Consent: I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research study, and my questions have been answered. I am prepared to participate in the research study described above. I will be offered a copy of this consent form after I sign it.

____

Participant’s Signature Date

____

Participant’s Name

____

Researcher’s Signature Date

Appendix E

Lean Six Sigma Summarized Course Topics

Lesson 1, Topic: Six Sigma

- Six Sigma: Why Six Sigma, Does It Apply To Me, Is About Success (slides 3-5)
- Six Sigma: Deployment Strategies, At Most Companies, Critical Success Factors (slides 6-8)
- What is Six Sigma? (slides 9-13) (Caterpillar Inc., 2000)
- Six Sigma Focus on Reduction of Variation (slides 14-17)
- Six Sigma Success Factors (slide 18)

Lesson 2, Topic: Six Sigma Process Tools

- DMAIC Improvement Process (slides 3-9)
- DMEDI Creation Process (slides 10-15)
- DMADV Process & Differences (slides 16-18)

Lesson 3, Topic: Lean & Lean Six Sigma and Six Sigma Rules & Responsibilities

- Gains From Lean Six Sigma (slides 3-4)
- What Is Lean? (slides 5-6)
    - 8 Wastes (slide 7)
    - 5 S's (slides 8-10)
    - KPI's & Results of Lean (slides 11-12)
- Lean Six Sigma (slides 13-24)
- Six Sigma Roles & Responsibilities (slides 25-30)

Lesson 4, Topic: Six Sigma & Lean Tools

- Six Sigma Tools & Kaizen (slides 3-9)
- Lean Tools List (all tools listed in notes) (slide 10)
- House of Lean Six Sigma (all tools listed in notes) (slide 11)

Lesson 5, Topic: DMAIC- Define

- Clear Definition and Developing Business Opportunity (slides 3-5)
- Project Charter (slides 6-16)
- Tools Used in Define Stage (slides 17-44)
  - SIPOC Diagram
  - Process Mapping
  - Upper-Level Process Maps
  - Process Steps Within Boundaries
  - Process Input Variables
  - Functional Deployment Mapping
  - Flow Charts

Lesson 6, Topic: DMAIC- Measure

- Measure Performance Overview (slides 3-4)
- Key Performance Indicators to Meet Critical Customer Requirements (slides 5-13)
- Types of Variation & Charts (slides 14-28)
- Why Measure and Worry About Variation (slides 29-30)
- Measurement System Analysis (slides 31-41)
- Process Capability (slides 42-50) (Caterpillar Inc., 2000)

Lesson 7, Topic: DMAIC- Analyze

- DMAIC- Analyze (slides 3-4)
- Histograms & Pareto Analysis (slides 5-21)
- Sources of Variation (slides 22-34)
  - Ishikawa diagrams, Potential Root Causes, 5 Why's Analysis
- Scatter Diagrams (slides 35-40)
- C & E-Matrix (slides 41-48)
- Failure Modes / FMEA's (slides 49-56) (Caterpillar Inc., 2000)
- Mention of other tools used to Analyze data (slide 57)

Lesson 8, Topic: DMAIC- Improve

- DMAIC- Improve (slides 3-5)
- Generate Improvement Ideas(slides 6-8)
- Brainstorming (slides 9-13)
- Next Improvement Steps (slide 14)

Lesson 9, Topic: DMAIC- Control

- DMAIC- Control (slides 3-5)
- Weibull Distribution (slides 6-15)
- NPI & CPI (slides 16-17)
- What’s in It for Me? (slides 18)

VITA

VITA

JOHN MICHAEL DAVIS

EDUCATION:

PhD., Career and Technical Education, Purdue University, 2016
M.S., Industrial Technology, Eastern Illinois University, 1992
B.S., Industrial Technology, Eastern Illinois University, 1990
A.A.S, Instructional Systems Development, Community College of the Air Force, 1990
A.A.S, Aerospace Propulsion Technology, Community College of the Air Force, 1990

PROFESSIONAL EXPERIENCE:

Assistant Clinical Professor, 2009-Present
Vice President of Quality, 2007-2009
Senior Business Consultant, 2006-2007
Plant and Operations Manager, 1994-2006
USAFR Aircraft Maintenance Unit Superintendent, 2003-Present
USAF Technical Training Instructor, 1985-1993
USAF Aerospace Propulsion Technician, 1978-1993

PROFESSIONAL REGISTRATION/CERTIFICATION:

FAA Airframe and Powerplant Mechanic
FAA Private Pilot
CCAF Professional Manager
Project Management Professional
Lean Six Sigma Green Belt
USAF Master Technical Training Instructor
CCAF Aerospace Management Certificate

ACTIVE MEMBERSHIP IN PROFESSIONAL/SCIENTIFIC SOCIETIES:

Purdue University Representative to the Aviation Technician Education Council (ATEC)

PUBLICATIONS (2009 AND LATER):

Ropp, T. D., Amadou, A., & Davis, J. M. (2014). Incorporating 3D Printing as an Introduction to Digital Manufacturing in an Aeronautical Engineering Technology Curriculum. *ATEC Journal, (36)*2, 1-7

Ropp, T. D., Hedden, J. B., Mick, P. J., Davis, J. M., & Austin, S., Jr. (2012). Incorporating Advanced Aircraft Technologies into an Aeronautical Engineering Technology Curriculum. *Journal of Aviation Technology and Engineering, (2)*1, 5.

INSTITUTIONAL AND PROFESSIONAL SERVICE (2009 AND LATER):

Purdue Polytechnic Institute Faculty Senator, August 2015 – Present
School of Aviation and Transportation Technology Safety Committee Chair, August 2015 – Present
Aeronautical Technology: Engineering and Maintenance (ATeAM) Student Group Sponsor, April 2013 – Present
FAA Liaison, December 2010 – Present
FAA Part 147 Curriculum Co-Chair, January 2010 - Present
AT Curriculum Committee Member, August 2010 – Present
Test Cell Area Director for the National Test Facility for Fuel and Propulsion at Purdue University, January 2009 – Present
School of Aviation and Transportation Technology Safety Committee Member, September 2009 – Present

PROFESSIONAL DEVELOPMENT ACTIVITIES (2009 AND LATER):

Purdue Polytechnic Institute Transformation Phase 2 Workshop, June 2016
Purdue Polytechnic Institute Faculty & Staff Learning Innovation Workshop, May 2016
Fundamentals of Earned Value Management, Spring 2013
Fundamentals of Acquisition Management, Spring 2012
Boeing Extended Twin Engine Operations Course, Summer 2011