Journal of
INDUSTRIAL
TECHNOLOGY

Volume 20, Number 4 - September 2004 through December 2004

Understanding Six Sigma®: Implications for Industry and Education

By Mr. Sean P. Goffnett, CIT

Peer-Refereed Article

KEYWORD SEARCH

Curriculum
Higher Education
Leadership
Management
Quality
Quality Control

Sean Goffnett is a fulltime doctoral student and graduate assistant in the School of Engineering Technology at Eastern Michigan University. He has nearly a decade of industrial experience that ranges from manufacturing and assembly to product design and engineering. He is former Project Engineer and Six Sigma Black Belt for the Fortune 100 Company, Johnson Controls, Inc. Sean worked on a variety of Six Sigma projects spanning program management, computer aided design, and finite element analysis. He holds a Masters in Labor Relations and Human Resources from Michigan State University and a Masters in Engineering Management from Western Michigan University. He also holds two Bachelor Degrees, one in Industrial Technology from Central Michigan University and another in Plastics Engineering Technology from Ferris State University. Sean is a Certified Industrial Technologist and a Certified Workers' Compensation Professional. He is a member of the National Association of Industrial Technology, the American Society for Quality, and the Society of Human Resource Management. His current research interests include the technical and human aspects of quality, manufacturing, design, and engineering.

Understanding Six Sigma®: Implications for Industry and Education

By Mr. Sean P. Goffnett, CIT

People in industries from manufacturing to service are witnessing the growth of a strategic continuous improvement concept called Six Sigma. Tools, such as run charts and measurement system analyses, that a quality department might normally use for assurance purposes are expanding to all aspects of business, in part, by way of Six Sigma. This customer focused concept appears to thrive on process improvement and innovation, and it has been touted as a principal source for creating enormous savings and leading business strategy (Harry, 1998; Hoerl, 1998; Pande, Neuman, & Cavanagh, 2002). Six Sigma's main objectives are to reduce variation and defects, increase customer satisfaction, and increase profits (Goh, 2002; Hahn, Hill, Hoerl, & Zinkgraf, 1999; Harry, 1998). What is more, people are now witnessing the first wave of Six Sigma in academia. For example, Eastern Michigan University, Arizona State University and Virginia Tech each offer a Six Sigma course (Hoerl & Bryce, 2004; Zahn, Watson, Voelkel, & Patterson, 2003).

The growth of Six Sigma in both industry and academia has created some confusion and a consequential need for a greater understanding on the subject. For instance, a number of individuals consider Six Sigma an industry trend that offers nothing new (Clifford, 2001; Dalgleish, 2003; Stamatis, 2000). Some believe that Six Sigma is strictly for use by individuals and organizations with a technical orientation. There are scores of small businesses and service oriented organizations, such as health offices and universities, who believe Six Sigma is solely for large manufacturing organizations (Gnibus & Krull, 2003; Smith, 2003).

There are questions and concerns with Six Sigma research, its applications, definition, approach, and preparation. For example, there are numerous publications on Six Sigma today that include case studies, comprehensive discussions, and a rapidly growing number of books and websites, the sheer magnitude is compelling, but to date there has been little conclusive empirical research regarding Six Sigma's influence on industry (Goh, 2002). Empirical research examining interactions and influences of Six Sigma relative to business metrics, cultures, laws, unions, teams, and so forth is largely absent from much of today's literature. In addition, little information exists about Six Sigma's influence on academia (e.g., curriculum and accreditation) and vice versa.

Academia is an obvious partner to business and holds an important role in the exploration, understanding, and diffusion of contemporary industrial concepts. Experts in academia decide what is appropriate for student preparation. Accrediting institution like the American Association of Collegiate Schools of Business (AACSB) (2003), Accreditation Board of Engineering and Technology (ABET) (2003), and the National Association of Industrial Technology (NAIT) (2003) are not out to mandate what experts in academia decide to teach and research, but are there, for example, to represent industry and students and to serve as guides in defining programs (Ward & Dugger, 2002). Preparing students for work in industry is a common accrediting principle shared by NAIT, ABET, and AACSB. A detailed comparison of these standards can be found in a 2002 work by Ward and Dugger.

Purpose

The purpose of this paper is to explore the fundamentals of Six Sigma and its connection with industry and academia in efforts to provide a greater understanding on the subject. This paper tries to offer insight by answering two general questions: First, what is Six Sigma? Second, if Six Sigma affects industry and academia, then what are some of the implications?
The basic premise and analysis in this study should foster an examination of the fit of Six Sigma in industry and academia. It may promote a re-examination of current curriculum and accrediting principles. Moreover, a possible reassessment of career goals and options for college graduates, academics, and various industry professionals might be warranted as a result of this study.

Methods

A literature review was the main research method used in this study where multiple scholarly sources provided collective insight into Six Sigma's history, definitions, practices, responsibilities, and training. In addition, a statistical depiction of an accredited curriculum was generated and then compared with Six Sigma training. The NAIT 2003 *Baccalaureate Program Directory* served as the population from which the sample group was drawn. This author chose not to name each program out of consideration and discretion for the institutions involved.

Accredited industrial and manufacturing management (industrial management) programs were identified by the author and confirmed directly by the NAIT. Each university's most recently published online undergraduate catalog that described the respective accredited baccalaureate programs' curriculum was obtained. Courses offered in industrial management programs were logically grouped by the author and compared with the basic training and skills required for Six Sigma. Descriptive statistics concerning the course offerings were determined for the NAIT accredited programs that made up the sample.

Background

Several comparable systems have come before Six Sigma, like Statistical Process Control (SPC), Lean, Kaizen, and Total Quality Management (TQM), which are utilized in industry and taught in academia. SPC, which has been in use for decades, is an essential device integrated into Six Sigma (Goh, 2002). SPC can function without falling under guise of Six Sigma, Lean, or TQM. Six Sigma, however, functions using many aspects of lean and quality control (Burton, n.d.; Drickhamer, 2002; Pyzdek, 2000a), which may indicate its ability to complement or run parallel to other initiatives and create cohesion between business processes (Bisgaard, Hoerl, & Snee, 2002).

Brief History of Six Sigma

In separate articles by two Motorola veterans, Mikel J. Harry (1998) and Dennis Sester (2001), each author explained how the idea of Six Sigma was first conceived by experts at Motorola in the early 1980s. Bob Galvin, who was chairperson of Motorola at the time, presented an incredibly demanding quality goal to his employees in 1981, which may have been the stimulus for Six Sigma. Engineer Bill Smith's research regarding process capability and defect reduction around 1985 became the basis for Six Sigma innovation. Leadership at Motorola later asked Mikel J. Harry, then part of Motorola's technical staff, to pioneer the strategic methodology that would soon become Six Sigma. Harry and his colleagues refined the Six Sigma strategy by decade's end.

Since then Six Sigma has been touted in numerous articles for having improved countless business processes as well as the overall vitality of several major organizations. Motorola, GE, Allied Signal [now Honeywell], Ford, Johnson Controls, TRW, Delphi, Raytheon, Lockheed-Martin, Texas Instruments, Sony, Bombardier, Polaroid, 3M, and American Express are some of the organizations that have implemented Six Sigma (Hahn *et al.*, 1999; Harry, 1998; Lanyon, 2003; Miller, 2001; Snee, 1999; Williams, 2003). Most organizations on this growing list claimed to have saved millions of dollars with Six Sigma. However, provable figures were not available. Motorola, GE, and Honeywell, three notables that all claimed to have saved an exorbitant amount of money with Six Sigma, are revered in literature as the Six Sigma organizations to follow (Hahn *et al.*, 1999).

Six Sigma activities and achievements, seen mainly in large manufacturing operations, are also becoming more prevalent in small businesses, transactional business processes (e.g., HR and purchasing), and in the service sector (Gnibus & Krull, 2003; Goh, 2002; Hammer & Goding, 2001; Harry, 1998; Smith, 2003). Smaller companies have had similar financial success compared to larger companies but on a smaller scale (Brue, 2002; Gnibus & Krull, 2003; Harry, 1998). From at least a financial perspective, it appears that Six Sigma has had a considerable impact on numerous organizations across a variety of industries.

What is Six Sigma?

Some scholars and practitioners have attempted to describe Six Sigma in one or two definitions (e.g., Breyfogle, Cupello, & Meadows, 2001; Dambolena & Rao, 1994). However, many have concluded that there are at least three definitions (e.g., Adams, Gupta, & Wilson, 2003; Brue, 2002; Eckes, 2001; Pande & Holpp, 2002): Six Sigma can be viewed as a metric, a mindset, and a methodology.

The first logical and commonly heard definition for Six Sigma is that it is a statistical expression – a metric (Breyfogle *et al.*, 2001; Brue, 2002; Dambolena & Rao, 1994; Hahn *et al.*, 1999; Harry, 1998; Pande & Holpp, 2002). The lowercase Greek symbol (sigma) is the metric or fundamental statistical concept that denotes a population's standard deviation and is a measure of variation or dispersion about a mean. Mikel J. Harry (1998) and Forrest W. Breyfogle *et al.* (2001) among others explained how Six Sigma can be defined as a term for process performance that produces a mere 3.4 defects per million opportunities (DPMO). Readers should see Harry (1998) for a detailed explanation of this figure. In layperson terms, Six Sigma is a metric representing a process that is performing virtually free of all defects.

As a second definition, Six Sigma is considered an organizational mindset that emphasizes customer focus and creative process improvement (Brue, 2002; Dambolena & Rao, 1994; Hahn *et al.*, 1999; Harry, 1998; Pande & Holpp, 2002). As Mikel J. Harry (1998) aptly stated, "The philosophy of Six Sigma recognizes that there is a direct correlation between the number of product defects, wasted operating costs, and the level of customer satisfaction" (p. 60). With this mindset, individuals are prepared to work in teams in order to achieve Six Sigma and its ultimate goal of reducing process variation to no more than 3.4 defects per million opportunities (Harry, 1998). In their book, *Six Sigma Deployment,* Cary Adams, Praveen Gupta, and Charles Wilson, Jr. (2003) maintained that, "Five sigma will not meet customer requirements, and seven will not add significant value. Six Sigma's 3.4 parts per million is close to perfection, and that makes it a more attainable and realistic goal to achieve" (p. 8). Interestingly, the vast majority of processes found in U.S. companies are said to linger near four sigma or less (Breyfogle *et al.*, 2001; Harry, 1998).

As a third definition, Six Sigma is viewed as a strategic improvement methodology termed DMAIC (Breyfogle *et al.*, 2001; Brue, 2002; Eckes, 2001; Hahn *et al.*, 1999; Harry, 1998; Pande & Holpp, 2002; Pande *et al.*, 2002). DMAIC is an abbreviation of the five systematic steps in the Six Sigma methodology. The steps used for breakthrough thinking and improvements are: define, measure, analyze, improve, and control. This methodology is used to carry out the structured philosophy of Six Sigma in places that include but are not limited to manufacturing, design, engineering, human resources, purchasing, and customer service. Table 1-1 was developed to illustrate the steps and various tools that can be utilized in Six Sigma.

Six Sigma's DMAIC Methodology

Define (D) is the first step of the Six Sigma methodology where leaders are expected to select projects, set initial goals or targets, and develop a project charter or statement of work (SOW). Costs of poor quality associated with the new or existing process being analyzed are estimated. Improvement targets are set often in terms of sigma and cost (Pande *et al.*, 2002). Leadership selects the appropriate team members. The team then determines more precisely the criteria that are critical to the customer. Run charts, interviews, or surveys, for example, are utilized to obtain leads and useable figures (Eckes, 2001). A high-level process map of the existing process is to be developed with start and end-points clearly illustrated. Strategic deliverables are a process map, a working project charter, a team roster, and the costs of poor quality. A progress report to leadership normally concludes each step (Eckes, 2001; Pande *et al.*, 2002).

Measure is the second step of the Six Sigma methodology and is denoted by the capital letter M. This is where a baseline measure is taken using actual data (Eckes, 2001; Pande *et al.*, 2002; Snee, 2003). The measure then becomes the origin from which the team can gauge improvement. The team develops measures or utilizes existing ones, such as SPC data or database information, and pairs them accordingly with critical customer criteria. Pareto diagrams and controls charts as well as methods mentioned above in the define step are possible data sources for baseline measures. Testing repeatability and reproducibility (R&R) of a measurement system is recommended throughout a Six Sigma project wherever critical measures are taken. A data gathering plan or sampling plan can be followed for greater accuracy (Eckes, 2001; Pande *et al.*, 2002). The project charter or SOW should be refined based on the data gathered in the measure step. The process map can be revised based on new discoveries of value added or non-value added steps in the existing process. Strategic deliverables for the measure step are baseline figures, R&R results, process capability, an improvement goal, a refined process map, and a refined project charter (Eckes, 2001; Pande *et al.*, 2002).

The third step, A, is analyze. Here teams identify several possible causes (X's) of variation or defects that are affecting the outputs (Y's) of the process. One of the most frequently used tools in the analyze step is the cause and effect diagram (Eckes, 2001; Snee, 2003). A Six Sigma team explores possible causes that might originate from sources, such as people, machinery and equipment, environment, materials, and methods. Another highly effective technique to expose root cause is asking "why" to a possible cause at least five times (Eckes, 2001). Team member suggestions may need clarified before proceeding further, so each and every team member has a clear understanding of the cause being presented. The resulting list should be reduced to the most probable root causes. Causes can be validated using new or existing data and applicable statistical tools, such as scatter plots, hypothesis testing, ANOVA, regression, or design of experiments (DOE). Experts warn not to assume causation or causal relationships unless there is clear proof. Furthermore, validating root causes can help teams avoid implementing ineffective improvements and wasting valuable resources (Eckes, 2001). Root cause is the number one team deliverable coming out of the analyze step (Eckes, 2001; Pande *et al.*, 2002).

The team then enters the improve (I) step. Here a team would brainstorm to come up with countermeasures and lasting process improvements that address validated root causes. The tool most preferred for this process is the affinity diagram, which is a brainstorming technique where a topic or issue is presented to a small team who then quickly list ideas or solutions (Eckes, 2001). The team should narrow the list to one or two potential improvements that are step deliverables for small-scale implementation. Improvements should be selected based on probability of success, time to execute, impact on resources, and cost (Eckes, 2001; Pande *et al.*, 2002). If newly gathered data indicates the small-scale implementation is a legitimate success, teams should proceed to full-scale implementation (Pande *et al.*, 2002).

The final step for at least the black belt and many of the team members is control, which is signified by the capital letter C. At this point devices should be put in place to give early signals when a process is heading out of control. Teams may develop poka-yokes or mistake proof devices that utilize light, sound, logic programming, or no-go design to help control a process (Breyfogle *et al.*, 2001). The ultimate goal for this step is to reduce variation by controlling X's (i.e., the inputs) and monitoring the Y or Y's (i.e., the outputs) (Pande *et al.*, 2002).

In approximately three to six months, the sigma levels or process capability figures, that should be routinely measured and documented by workers, are then checked by the process owner to make certain that the installed improvements are lasting. Any documentation and project reports should be finalized. With a control plan in place, the project is delivered to the rightful owner who is usually the project champion or a sponsor from leadership. It is the owner's duty to then manage the new or improved process (Eckes, 2001; Pande *et al.*, 2002). If Six Sigma was not achieved, a separate project can be kicked off in the future to address any residual root cause (see Table 1-1 on page 6).

Roles & Responsibilities for Six Sigma

Several experts have recognized the various roles in Six Sigma (Adams *et al.*, 2003; Breyfogle *et al.*, 2001; Brue, 2002; Eckes, 2001; Hahn, Doganaksoy, & Hoerl, 2000; Hoerl, 2001; Pande *et al.*, 2002; Pyzdek, 2000b). George Eckes (2001, 42) maintained that team sponsor, champion, master black belt, black belt or green belt, and team members make up the core of Six Sigma. Like champions and master black belts, executives work behind the scenes to support people working on projects and the overall initiative. The reader should see Eckes (2001) for full descriptions of each role.

The front line leaders of Six Sigma are called black belts. These individuals are full-time project leaders with all the same responsibilities as green belts. However, black belts receive significantly more training than green belts (e.g., 4 weeks vs. 1 week) and are expected to generate more results from larger scope projects (Hoerl, 2001).

Black belt candidates are described as disciplined problem solvers who possess a fair amount of technical ability, are comfortable with basic statistics, and are not afraid to question conventional wisdom (Hoerl, 2001; Adams *et al.*, 2003). A black belt has also been described as an open-mined change agent and project manager who must be able to communicate effectively at all levels (Brue, 2002). Many experts have insisted that black belts be able to use a broad set of soft skills, such as meeting management and presentation methods (Breyfogle *et al.*, 2001; Eckes, 2001; Hoerl, 2001; Pyzdek, 2000b). As a chosen leader, the black belt will guide a team through DMAIC.

Black belts are "future business leaders" (Eckes, 2001, p. 43) and "the backbone of Six Sigma culture" (Brue, 2002, p. 86). Cary W. Adams *et al.* (2003) insisted that black belts are in strong demand and should be selected based on management potential. They make up on average roughly two percent of an organization's workforce. Their voluntary assignment is usually temporary lasting anywhere from two to three years. These trained individuals are expected to focus their efforts fulltime in the black belt role over this two to three year period and are not to be distracted with tasks from the role he or she temporarily left. Under these conditions, a black belt can complete approximately four to six projects in a twelve month period. There is generally an estimated annual savings of one million dollars in total for all projects completed in this timeframe (Adams *et al.*, 2003; Harry, 1998; Hoerl, 1998). A prolific first year in Six Sigma can result in certification or reward and recognition by the company.

Training for Becoming a Six Sigma Black Belt

Black belt is the designation for a leader of Six Sigma. Black belt training covers the strategic steps (i.e., DMAIC) typically carried out in a Six Sigma project. DMAIC is generally covered with some overlap over four non-consecutive weeks: DM in week 1; MA in week 2; AI in week 3; and IC in week 4. The time between training sessions is anywhere from two to four weeks, or enough time to apply what was learned in a session to a real project (Hoerl, 2001). A recommended curriculum created by Hahn *et al.* (1999) that outlines the extensive week-by-week training for black belts is provided in Figure 1-1 (see page 7).

Comparison of Curriculum to Training

If Six Sigma aptitude is becoming part of the requisite knowledge in contemporary industry, then according to most accrediting bodies, educational institutions should address this requirement. The logical subject groupings used for this study were derived from information given in Table 1-1 and Figure 1-1 that describe the characteristics and training of Six Sigma. Potential leaders of industry should be skilled in the following areas:

- General Processes (e.g., manufacturing planning, operations management)
- Statistics (i.e., a course or series of courses independent from quality);
- Quality (e.g., SPC, TQM, and continuous improvement);
- Management (e.g., industrial supervision, strategy, and human resources);
- Business (e.g., economics, finance, and accounting);
- Project Management;
- Communications (e.g., technical writing, reports and presentation); and

Table 1-1 Six Sigma Strategic Methodology, Section Deliverables, and Traditional Tools

Strategic Steps	Common Strategic Section Deliverables	Traditional Tools
Define	Project Charter or Statement of Work (SOW) -Process and Problem -Scope and Boundaries -Team, Customers & Critical Concerns -Improvement Goals & Objectives -Estimate Sigma & Cost of Poor Quality (COPQ) Gantt Chart / Timeline High Level Process Map Step Documentation and Next Steps Exit Review	Spreadsheet/Word Processor Critical to Customer Concept Project Charter or SOW Gantt Chart / Timeline Flowchart or Process Map Balanced Scorecards Pareto Chart & Control Charts QFD / House of Quality Suggestions / Complaints Surveys / Interviews / Focus Groups
Measure	Baseline Figures (Sigma & Cost) Process Capability Measurement System Analysis (MSA) or Gage R&R Refine Project Charter, including COPQ Refine Process Map Fix Gantt Chart / Timeline SIPOC or IPO Diagram Step Documentation and Next Steps Exit Review	Data Gathering Plan Surveys / Interviews / Focus Groups Checksheets / Spreadsheets SIPOC or IPO Diagram Descriptive Statistics & Capability Pareto Chart / Control Charts Measurement System Analysis Flowchart or Process Map Project Charter or SOW Gantt Chart / Timeline
Analyze	Identified Root Cause(s) -Cause and Effect -Statistical Analyses Validated Root Cause(s) Step Documentation and Next Steps Exit Review	Fishbone Diagram (5-Why) FMEA Interrelationship Diagram Histogram Scatter Diagrams (Correlation) Hyp Testing / Chi-Square Confidence Intervals Pareto Chart / Control Charts Regression ANOVA DOE Response Surface Methods Flowchart or Process Map
Improve	Selected Root Cause(s) & Countermeasures Improvement Implementation Plan Validated Solutions or Improvements -Statistical Analyses Revised Flowchart or Process Map Step Documentation and Next Steps Exit Review	Affinity Diagram Hypothesis Testing Confidence Intervals DOE FMEA Trial and Error / Simulation Flowchart or Process Map Implementation & Validation Plan
Control	Control Plan -Tolerances, Controls, and Measures -Charts and Monitor -Standard Operating Procedures (SOP) Response Plan -Ownership or Responsibilities -Corrective Actions Validated In-Control Process and Benefits -Process Capability -Measurement System Analysis (MSA) or Gage R&R Step Documentation and Final Report Exit Review - Project Completion and Handoff to Owner	Control Charts Process Map / Monitor / Response Plan Poka-Yokes Standardization SOP / Work Instructions Process Dashboards Capability Studies MSA or Gage R&R Documentation Final Report Presentation

Note: tools should be used only as necessary

- Computer Applications (e.g., spreadsheets, programming, and databases)

For the purpose of this study, NAIT accredited industrial management programs were assumed to encompass the core knowledge of Six Sigma. These accredited programs would most likely include both technical and business subject matter. The comparison of Six Sigma training to NAIT accredited industrial management curriculum was concerned most with applied courses, specifically managerial and technical offerings that establish core industrial knowledge.

The author, with assistance from the NAIT, identified all NAIT accredited industrial management programs for use in this study. Current data was available for most of the programs. Table 1-2 below gives a concise breakdown showing basic descriptive statistics of the sample and the Six Sigma skills (e.g., processes, statistics, quality, etc.) thought to be required as part of management and technical offerings in the NAIT accredited programs.

Results

When assessing the sampled NAIT accredited industrial management programs, curriculum constituting comprehensive training in Six Sigma was found slightly deficient. Not a single Six Sigma course was offered, but considering it is still emerging in industry,

Figure 1-1 Six Sigma - Typical BB Training Curriculum [Excerpted from Hahn et al. (1999) p. 210]

Week 1:
Six Sigma Overview & the MAIC Roadmap
Process Mapping
QFD (Quality Function Deployment)
FMEA (Failure Mode and Effects Analysis)
Organizational Effectiveness Concepts
Basic Stats Using Minitab
Process Capability
Measurement System Analysis

Week 2:
Review of Key Week 1 Topics
Statistical Thinking
Hypothesis Testing and Confidence Intervals (F, t, etc.)
Correlation
Multi-vari Analysis and Regression
Team Assessment

Week 3:
ANOVA
DOE (Design of Experiments)
Factorial Experiments
Fractional Factorials
Balanced Block Designs
Response Surface Designs
Multiple Regression
Facilitation Tools

Week 4:
Control Plans
Mistake-Proofing
Team Development
Parallel Special Discrete, Continuous Process, Administration, and Design Tracks
Final Exercise

Notes:
1. Project reviews are done each day in weeks 1-4
2. Hands-on exercises on most days
3. Three weeks of applied time between sessions

Table 1-2 Six Sigma Assemblage of Skills & Curriculum Analysis

Six Sigma Skills	1	2	3	4	5	6	7	8	9	10	11	12	NO	YES	TOTAL	NO	YES
Processes	Y	**N**	Y	Y	Y	Y	Y	Y	Y	Y	Y	na	1	10	11	9%	91%
Statistics	**N**	Y	**N**	Y	Y	Y	Y	Y	**N**	**N**	Y	na	4	7	11	36%	64%
Quality	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	na	0	11	11	0%	100%
Management	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	na	1	10	11	9%	91%
Business	Y	Y	Y	**N**	Y	Y	**N**	Y	Y	Y	Y	na	2	9	11	18%	82%
Project Management	**N**	Y	**N**	**N**	Y	**N**	**N**	**N**	**N**	Y	**N**	na	8	3	11	73%	27%
Communications	Y	Y	Y	Y	**N**	N	Y	Y	Y	Y	**N**	na	3	8	11	27%	73%
Computer Apps.	Y	Y	Y	Y	Y	**N**	Y	**N**	Y	Y	Y	na	2	9	11	18%	82%
NAIT Region	3	5	3	2	2	4	4	4	3	3	2	3				Average	76%

Note: The above is a sample of NAIT accredited industrial management programs a specific course was not expected to be offered at this point. However, according to Joseph G. Voelkel (Zahn *et al.*, 2003), associate professor and department chair for the Rochester Institute of Technology's college of engineering, a number of institutions (outside NAIT) have started to offer coursework and certification in Six Sigma. Current quality and continuous improvement courses presumably mention Six Sigma. One limitation is that an extensive analysis of actual course content was not part of this study.

The data from Table 1-2 shows that the average NAIT accredited industrial management program will most likely require that individuals be trained in processes (91%), quality (100%), management (91%), business (82%), and computer applications (82%), and will less likely be taught statistics (64%), project management (27%), and technical communications (73%), which are all essential to Six Sigma training. The curriculum, in this author's opinion, appears to fall short of the training. Gaps are likely to be larger for specialized engineering or industrial technology programs as well as for business degrees. For example, business programs may require statistics but place little or no emphasis on courses in quality or manufacturing processes.

Implications

The implications stemming from this literature review and brief study pertain to several key segments of industry and academia. For instance, Six Sigma appears to influence students, professionals and practitioners, educators and administrators, accredited and non-accredited programs, and industrial and educational organizations as a whole.

Students

The data in Table 1-2 showed that the average NAIT accredited curriculum offered less than 80% of the knowledge and skill required for Six Sigma. Noticeable gaps were found to exist between what is offered by the NAIT accredited programs sampled for this study and what is offered by Six Sigma training. For instance, being versed in statistics is necessary for complex problem solving and data-driven decision making. SPC and many powerful statistical methods, such as regression, are essential facets of Six Sigma training. Only 64% of the sampled NAIT accredited programs required the taking of an independent statistics course, one or a combination thereof that may cover probability and statistics to a degree that is comparable to the experience in Six Sigma training (see Figure 1-1).

It would seem that most college graduates are not fully prepared to be certified as Six Sigma black belts, but could, however, make an impact in a role of green belt or as a highly desirable Six Sigma team member. Minor revisions to curriculum to include more teachings on the definitions, strategic steps, roles, and tools of Six Sigma could possibly fill this void. Advanced curriculum, however, could not be expected to replace valuable corporate training, hands-on experience, or individual ambition.

Professionals and Practitioners

Six Sigma training is opening doors to new roles and positions within organizations (DeFeo, 2000; Hoerl, 1998). Using Six Sigma as a career ladder, graduates could still serve in traditional positions, or they could take advantage of opportunities to work and advance in more non-traditional roles. Training and participating in Six Sigma has its benefits (e.g., recognition, pay increase). For instance, to advance in major organizations like GE, one must be trained in Six Sigma and have played an active part in generating improvements (DeFeo, 2000; Eckes, 2001).

Programs, Professors, Educators, and Administrators

Gerald Hahn *et al.* (2000) strongly suggested to "engage suppliers" (p. 324), which would include academia since one of its major functions or services is to develop future leaders of industry. Ronald Snee (1999) argued that "because Six Sigma can be applied to any industry, it's important to introduce students to the subject as they will likely be involved in Six Sigma or other improvement initiatives at sometime in their career" (p. 103). Faculty might consider integrating and introducing more concepts related to strategy and improvement in a special course or across a variety of courses, which could possibly increase learning and retention through harnessing Six Sigma training techniques in the class (Hoerl *et al.*, 2004; Snee, 2000; Zahn *et al.*, 2003). Customer satisfaction, particularly employer satisfaction with graduates, is a major indicator of a program's effectiveness, and is a measure that should be continually assessed for possible improvement (Ward & Dugger, 2002).

Organizations

Organizations continue to scramble in this frenzied global marketplace as more demands are made in areas such as innovation, customer satisfaction, and competitiveness (DeFeo, 2000). Hidden waste and variation add to the chaos. Those that choose not to improve their competitive position or become complacent in their thinking could become non-existent. To avoid industrial extinction, organizations should not only aim at hiring the best [prepared] individuals for work but should also consider revising and aligning business strategies to achieve more positive outcomes. Six Sigma is one way to link overall strategy to all important business processes (Bisgaard, *et al.*, 2002; Harry, 1998; Pande *et al.*, 2002). The growing acceptance of Six Sigma, including its alleged improvements and financial successes, over the last decade could indicate a considerable impact on industry and demonstrate that Six Sigma is not a mere trend or fad (Goh *et al.*, 2003; Harry, 1998; Hoerl 1998).

Summary & Conclusion

The purpose of this paper has been to better understand what Six Sigma is as described by a rapidly developing body of literature. Six Sigma is generally described as a metric, a mindset, and a methodology for strategic management and process improvement. Six Sigma has numerous strengths and a near equal amount of weaknesses, which implies that it is not perfect and should not be mistaken for a solution to all problems (Goh, 2002). Six Sigma should not be mistaken as something that is suitable for all people and all organizations, universities included. However, Six Sigma has been around for over a decade and is still growing to the extent that more people and more organizations should probably be prepared.

The study tried to clarify some of Six Sigma's expanding influence on industry and academia. For instance, what is being reported by industry experts, from manufacturing to service, is that over the last decade the growing number of small to large organizations who have implemented Six Sigma have produced some astounding results measured collectively in the billions of dollars. In addition, Six Sigma has created new roles in industry and an increasing need for this particular knowledge and skill. Black belts, for example, are trained leaders of Six Sigma. The initiative's success, it would seem, stems from having a highly trained workforce. Though, more research is required to determine the true extent of Six Sigma's success and influence on industry and academia.

A comparison of the average NAIT accredited industrial management curriculum and Six Sigma training indicates certain professionals may not be fully prepared for some of the complex work and continuous improvement efforts that are growing in industry. Many graduates should be prepared to add value to an organization. Based on the amount of human capital owned at the end of an investment in higher education, many graduates should be prepared. Those who possess most of the requisite skills for Six Sigma and have a clear understanding of contemporary industrial concepts should be prepared to improve new and existing processes and make positive and productive contributions immediately in the workplace.

References

AACSB (2003). *Eligibility procedures and standards for business accreditation 2003*. Retrieved from www.aacsb.edu/accreditation/standards.asp

ABET (2003). *Accreditation policy and procedure manual 2003-04*. Retrieved from www.abet.org/policies.html

Adams, C. W., Gupta, P., & Wilson, Jr., C. E. (2003). *Six Sigma deployment*. Boston: Butterworth-Heinemann.

Bisgaard, S., Hoerl, R. W., & Snee, R. D. (2002). Improving business processes with Six Sigma. *Quality Congress*, 701-704.

Breyfogle, F. W., Cupello, J. M., & Meadows, B. (2001). *Managing Six Sigma: A practical guide to understanding, assessing, and implementing the strategy that yields bottom-line success.* New York: John Wiley & Sons.

Brue, G. (2002). *Six Sigma for managers*. New York: McGraw-Hill.

Burton, T. T. (n.d.). Is this a Six Sigma, Lean, or Kaizen project? Retrieved from www.isixsigma.com.

Clifford, L. (2001, January). Why you can safely ignore Six Sigma. *Fortune,* 143(2), 140.

Dalgleish, S. (2003). Six Sigma? No thanks. *Quality,* 42(4), 22.

Dambolena, I. & Rao, A. (1994). What is Six Sigma anyway? *Quality*, 33(11), 10.

DeFeo, J. A. (2000). Six Sigma: New opportunities for HR, new career growth for employees. *Employment Relations Today,* 27(2), 1-6.

Drickhamer, D. (2002, May). Where lean meets Six Sigma. *Industry Week,* 251(4), 55.

Eckes, G. (2001). *The Six Sigma revolution: How General Electric and others turned process into profits*. New York: John Wiley & Sons.

Gnibus, R. J., & Krull, R. (2003). Small companies see the money. *Quality,* 42(8), 48-51.

Goh, T. N. (2002). A strategic assessment of Six Sigma. *Quality and Reliability Engineering International*, 18, 403-410.

Goh, T. N., Low, P. C., Tsui, K. L., & Xie, M. (2003). Impact of Six Sigma implementation on stock price performance. *Total Quality Management & Business Excellence,* 14(7), 753-763.

Hammer, M., & Goding, J. (2001). Putting Six Sigma in perspective. *Quality,* 40(10), 58-62.

Hahn, G. J., Hill, W. J., Hoerl, R. W., & Zinkgraf, S. A. (1999). The impact of Six Sigma improvement – a glimpse into the future of statistics. *The American Statistician*, 53(3), 208-215.

Hahn, G. J., Doganaksoy, N., & Hoerl, R. W. (2000). The evolution of Six Sigma. *Quality Engineering*, 12(3), 317-326.

Harry, M. J. (1998, May). Six Sigma: A breakthrough strategy for profitability. *Quality Progress*, 31(5), 60-64.

Hoerl, R. W. (1998). Six Sigma and the future of the quality profession. *Quality Progress,* 32(6), 35-42.

Hoerl, R. W. (2001). Six Sigma black belts: What do they need to know? *Journal of Quality Technology* 33(4), 391-406.

Hoerl, R. W., & Bryce, G. R. (2004, February). What influence is the Six Sigma movement having in universities? What influence should it be having? *ASQ Six Sigma Forum Magazine,* 3(2), 37- 40.

Lanyon, S. (2003) At Raytheon Six Sigma works, too, to improve HR management processes. *Journal of Organizational Excellence,* 29-42.

Miller, W. H. (2001). New leader, new era. *Industry Week,* 250(14), 48-49.

NAIT (2003). *Industrial technology accreditation handbook – 2003*. Retrieved from www.nait.org

NAIT (2003). *National association of industrial technology 2003 Baccalaureate Program Directory*. Ann Arbor: NAIT University Division.

Pande, P. & Holpp, L. (2002). *What is Six Sigma?*. New York: McGraw-Hill.

Pande, P., Neuman, R. P., & Cavanagh, R. R. (2002) *The Six Sigma way team fieldbook: An implementation guide for process improvement teams*. New York: McGraw-Hill.

Pyzdek, T. (2000, January). Six Sigma and lean production. *Quality Digest,* 14. Retrieved from www.qualitydigest.com back issues.

Pyzdek, T. (2000, February). What is a black belt? *Quality Digest,* 22. Retrieved at www.qualitydigest.com back issues.

Sester, D. (2001). Motorola: a tradition of quality. *Quality*, 40(10), 30-34.

Smith, K. (2003, May). Six Sigma for the service sector. *Quality Digest*. Retrieved from www.qualitydiges.com back issues.

Snee, R. D. (1999). Why should statisticians pay attention to Six Sigma? *Quality Progress,* 32(9), 100-103.

Snee, R. D. (2000). Six Sigma improves both statistical training and processes. *Quality Progress* 33(10), 68-72.

Stamatis, D. H. (2000, May). Who needs Six Sigma, anyway? *Quality Digest.* Retrieved from www.qualitydigest.com back issues.

Zahn, D., Watson, G. H., Voelkel, J. G., & Patterson, A. (2003, November). What influence is the Six Sigma movement having in universities? What influence should it be having? *ASQ Six Sigma Forum Magazine,* 3(1), 33-38.

Ward, C. D., & Dugger, J. C. (2002). A comparison of selected categories of accreditation standards of NAIT, TEC-ABET, and AACSB. *Journal of Industrial Technology,* 18(3), 1-8. Retrieved from www.nait.org

Williams, T. A. (2003). Six Sigma is legit. *Quality,* 42(3), 6.