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A Case Study of How to Incorporate Cross-functional Components in Industrial Technology Education: Safety Metrics in the Classroom

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Introduction

Quality and safety are key factors influencing industrial productivity. Traditionally, statistical process control (SPC) has been utilized by manufacturing companies to monitor, identify and remedy quality problems associated with industrial processes and manufactured goods. The root causes of quality problems (i.e., methods, measurements, machines, materials) also contribute to the occurrence of industrial injuries. While much has been written about the application of SPC methods to safety, very little has been written about the instructional aspect of this interface. Current interest in the integrated development of practice to education has created cross-functional curriculum models. Cross-functional instruction has received much attention in all levels and disciplines of education (Wagner, Najdawi & Otto, 2000; DeMoranville & Aurand, 2001; Rothstein, 2002; Anthony, 2000). Educators credit its effectiveness to curricula designed to teach objectives by contextual learning (Resnick & Klopfer, 1989). Learning in context provides a forum by which students can make the connection between classroom instruction and real world environments. Recently, cross-functional education has begun appearing in Industrial Technology (IT) curricula (Freeman & Field, 1999; Meier, 2000). This paper documents a collaborative venture with industry to develop an instructional module for exposing IT students to the cross-functional nature of safety metrics.

What are Safety Metrics?

Over the years, a number of safety professionals have begun exploiting proven scientific measures to improve safety systems. This phenomenon has been instrumental in the use of statistical methods to collect, organize, monitor and analyze accident data (Krause, 1995). Unfortunately, statistical techniques, or more specifically SPC tools, are underutilized in occupational safety and health because most safety professionals lack academic training in statistics (Kohn, 1997). Despite inherent difficulties in learning and applying statistical procedures, safety practitioners contend that statistics can assist organizations to control variation in safety performance (Salazar, 1989; Esposito, 1993; Seymour, 1998; Sorrell, 1998). Safety metrics provides professionals with tools and techniques to establish a bona fide safety program. It generates a systematic approach to collecting, analyzing and monitoring safety initiatives.

According to Janicak (2003):

> *The main focus for a safety metrics program is the identification of gaps or deficiencies in the data obtained versus the desired outcome as established in the program goals or benchmarks. Identification of these deficiencies can be readily achieved through the use of control charts and various statistical techniques. (p. xvii)*

Interestingly, the use of safety metrics extends beyond the borders of industry. Its wide applications range from studying behavior patterns in clinical psychology (Peadt & Wheeler, 1995; Hantula, 1995) to analyzing incidents associated with packaging and transportation of hazardous materials by the US Department of Energy (2001).

Janicak (2003) credits the increased popularity of total quality management (TQM) for the acceptance of safety metrics by industry as a viable approach to measuring safety performance. The literature has many anecdotes describing the influence TQM has had on improving industrial organizations and educational programs (Wang & Miller, 1999). Salazar (1993) links four underlying TQM themes to safety metrics. These include (a) continuous improvement, (b) employee training, (c) defect prevention and (d) employee participation. Consequently, there is tremendous career potential for IT program graduates who possess applied knowledge of safety metrics. This premise challenges the IT educator to design a method for incorporating safety metrics into existing curricula. A cross-functional approach to classroom instruction of safety metrics befits this type of educational opportunity.

Cross-functional Curriculum: Initializing the Experience

IT students are expected to work in industrial environments comprising myriad operations that test their academic preparedness and technical knowledge. Similarly, IT faculty are constantly faced with assessing the relevancy of their programs to the performance of graduates on the job (Zargari & Hayes, 1999). Meier (2000) captures this challenge by noting, "Industrial Technology faculty and students need to understand the connections and linkages among a wide variety of business and management concepts to better prepare themselves to succeed in the 21st century" (p. 2). Hence, the role of cross-functional education becomes increasingly important in preparing IT students entering dynamic working environments. Notably, Freeman and Field (1999) presented a model for operationalizing cross-functionality within IT programs. The essence of their innovation hinged on "incorporate[ing] the concepts of contextual learning and cognitive apprenticeships" (p. 2) within the framework of existing safety and manufacturing courses. The authors contend in their article that a function of safety professionals (as sanctioned by the American Society of Safety Engineers) is to "measure, audit, and evaluate the effectiveness of hazard controls and hazard control programs" (p. 2). However, they do not incorporate discussion on safety metrics in their thesis. Consequently, therein lies the rationale to expand on their cross-functional model to include safety metrics.

The proposed learning exercise outlines a methodology designed to integrate a safety metrics module in an IT program. The module will be created to overlap existing safety and quality assurance courses taught in a university located in the Southwest region of the United States. Course descriptions for the two courses involved in this undertaking are presented for clarity; both courses are part of the IT program's core curriculum. The course descriptions are:

Quality Assurance

A course designed to explore the various aspects of industrial quality and process control from a Total Quality Management (TQM) perspective. Statistical methods used for analyzing quantitative and qualitative data will are addressed. Inspection tools and methods for measuring product characteristics are covered. Laboratory activities provided. These activities allow students to become familiar with inspection techniques used to gather attributes and variables data.

Industrial Safety

Introduction to the field of industrial safety with emphasis placed on federal and state safety regulations. Critical safety aspects addressed include: accident investigation and reporting; the role of safety professionals; safety management; assessment of facilities for safety and health hazards.

Developing the Safety Metrics Module

Case studies provide faculty with relevant material that, if used effectively, can excite students to new levels of understanding and appreciation. To that end, it was the author's intent to obtain real-life injury data that could be statistically manipulated to determine an organization's safety performance. Operating under the premise of contextual learning (placing learning objectives within real-world applications), the company identified for the study represented one to whom students could relate. The semiconductor industry was a logical choice to target because of its geographical convenience to the University and also because of the microelectronics-manufacturing laboratory housed in the department where many students took courses.

Company officials agreed to the project on the conditions that (a) they remain anonymous in all published materials that resulted from the study and (b) furnished data was to be exclusively used for educational purposes. Two years of injury reports and workers' compensation claims data were provided. A combination of safety metrics tools (i.e., attributes charts, cause and effect analysis, Pareto analysis) was utilized to determine whether safety performance expectations were being met. Data analysis produced a snapshot of the organization's overall safety performance. However, the resultant quantity of information was too voluminous to be useful for instructional purposes. It was necessary to condense the findings into a manageable and meaningful education module.

Janicak (2003) observes that historically control charts have been used extensively to evaluate loss and accident information. He critically points out that the more informative charting techniques (i.e., cause and effect diagrams, Pareto diagrams) are "used only to a limited extent" (p. 3). Moreover, these two applications are user friendly and fairly easy to construct and interpret. These two techniques have been preferred as the means for accomplishing the cross-functionality of SPC and safety. Following is a brief description of each application along with findings and interpretations.

Pareto Analysis

Pareto analysis yields a visual means of readily identifying systemic problems of otherwise seemingly amorphous information. It is utilized for assessment of problem priorities and facilitates the separation of the vital few problems from the trivial many. Furthermore, through Pareto analysis, recentivity (the tendency to overestimate the importance of the most recent problem) is eliminated (Smith, 2001). Two types of Pareto charts were constructed: one by injury frequency and the other by injury cost. Over the two-year period (1999-2000), strains/sprains occurred at a higher rate in relation to the other types of injury categories (Figures 1 & 2). In addition, strains/sprains accounted for the greater portion of the company's cost associated with claims (Figures 3 & 4). In essence, the Pareto Chart assisted in pinpointing the type of injury that ran counter to the company's safety initiatives.

Cause and Effect Analysis

It was evident by the aforementioned Pareto analysis that the causes for strains and sprains needed examination. An effective instrument for the identification of injury causation is the cause-and-effect diagram. It is often referred to as the *fishbone diagram* because of its shape. To get to the root causes of a problem, each "rib" (the main frame) of the diagram is assigned one of six cause categories: environment, methods, measurements, personnel, materials and machines. The "bones" (possible causes) are subcategorized by causes of the cause. The subdividing continues until the root cause to the problem is found. The fishbone diagram for strains/sprains is found in Figure 5. Data revealed that the company's lax approach of enforcing housekeeping rules and its failure to provide a housekeeping checklist to employees created the opportunity for strains and sprains. Closer examination of the diagram found that poorly designed workstations were the cause for the large number of recorded strains/sprains. Employee injury investigation reports support the notion that poor designs were attributed to three things: (a) the industrial engineer was not consulted, (b) revisions had not been made to the station as recommended by the safety engineer and (b) material flow through certain workstations was unnecessary.

The Safety Metrics Module

Smith (1999) in his thesis on learning theories maintains that models of formalized instruction necessitate consideration of the process of learning and the role the educator will play in achieving outcomes. Consequently, it was prudent for the safety metrics module to emulate a proven methodology of instruction. To that end, the *cycle model of teaching* (Nasseh, 1996) was explored. This educational design was an appropriate choice because of its strong affinity to cross-functional theory. The safety metrics module was largely influenced by Nasseh's article "Changing Definition of Teaching and Learning" (1996). Nasseh presents compelling testimony for the immediate reconstruction of information technology curricula through application of the cycle model. In this model, four points of a cycle (subject, teaching, learning and outcome) are linked together. Specifically, "the values of the outcomes of learning to the students and job markets have influence in the design of the process of teaching and learning" (p. 2). Elements of the model as applied to safety metrics (Figure 6) are clarified below.

Subject:	Safety metrics
Teaching:	Integration of SPC and safety concepts.
Learning:	Safety metrics tools (Pareto analysis, cause and effect analysis).
Outcome:	Application of safety metrics to real-world environments.

The model exemplifies the crux of IT education: linking program objectives to working environments. This manifestation is possible through the bond and subsequent communication channel solidified between the educator, the student and employer. This model encourages conscious effort in soliciting student/employer input in addition to keeping abreast on contemporary industrial practices.

Implementing the Safety Metrics Module

Implementation of safety metrics into the IT curricula is targeted for the spring 2005 semester. The 45-50 minute module will be fashioned around the narrative and accompanying graphs described in this manuscript. Faculty will be allowed to customize the module to reflect the objectives of each course. In Industrial Safety for example, the safety metrics module will be incorporated with lecture five (see Figure 7). Discussion on the devastation that worker's compensation claims can have on a company's profit will be illuminated through the Pareto diagram. In addition, the cause and effect diagram will be an excellent segue into the second half of the lecture, accident prevention approaches in safety management. Students enrolled in Quality Assurance currently receive extensive instruction on control chart construction, application and interpretation. Safety metrics will be introduced as a component of problem solving techniques within the context of lecture number four (see Figure 8). Specific emphasis will be placed on the process of constructing the charts.

Summary

The infusion of diverse subject matter, especially safety and statistics, into existing curricula is not an easy task. However, the literature reveals that multidiscipline concepts and principles can be systematically interfaced through cross-functional education. Most importantly, contextual learning, linking theory to realistic environments, should be at the core of this type of curriculum design. This paper describes one tactic for integrating safety metrics into existing IT curricula. The safety metrics module evolved from a cross-functional curriculum model implemented at Iowa State University. Alternatively, the module outlined in this article was crafted around real-world injury records with the goal of being integrated into safety and quality assurance program frameworks. Implementation of the module will be viewed as an inroad to the expansion of cross-functional curriculum and its relevance to IT education. However, it could be deemed a starting point or rather a foundation from which extensive and more complex curricular interactions can evolve at other institutions.

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Figure 1. Pareto chart depicting injuries by type and cumulative percentages for the year 1999.

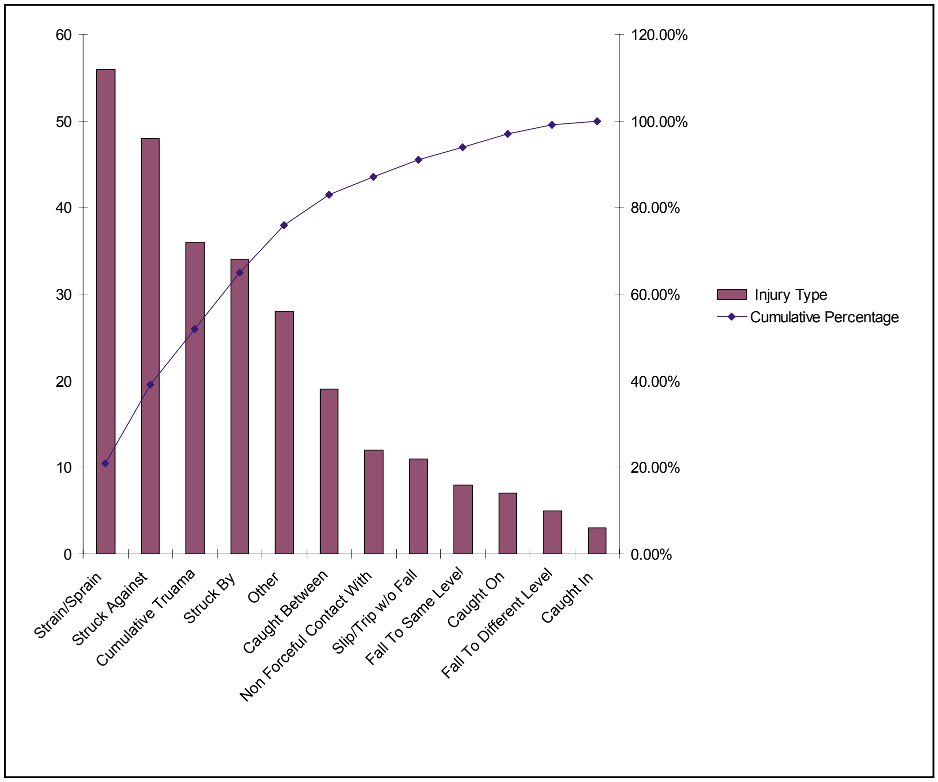

Figure 2. Pareto chart depicting injuries by type and cumulative percentages for the year 2000.

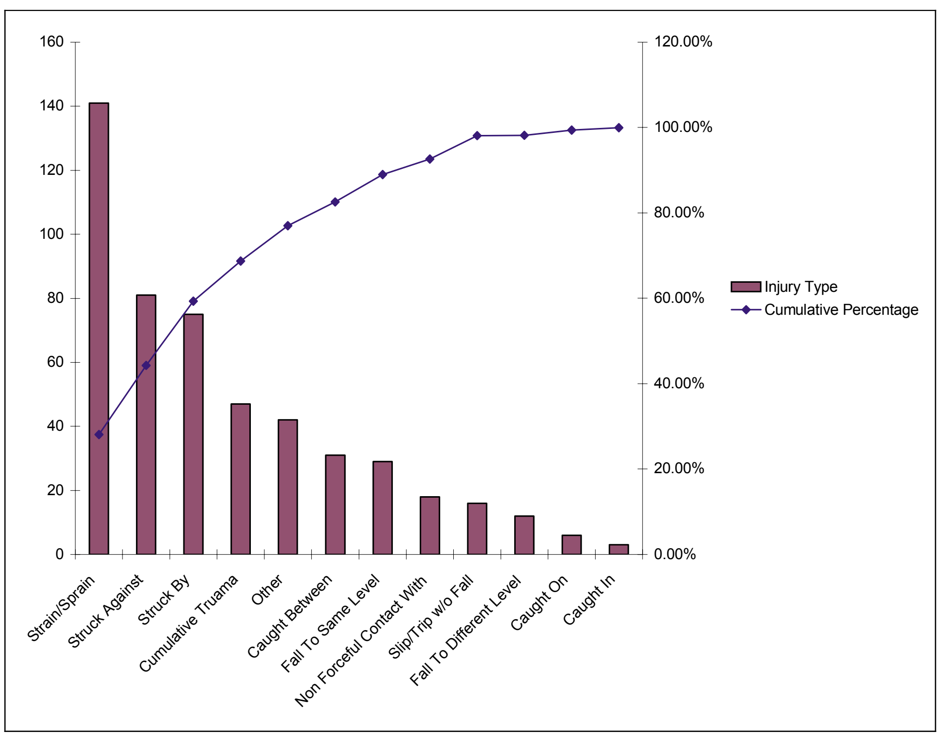

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Figure 3. Pareto chart depicting costs by injury type and cumulative percentages for the year 1999.

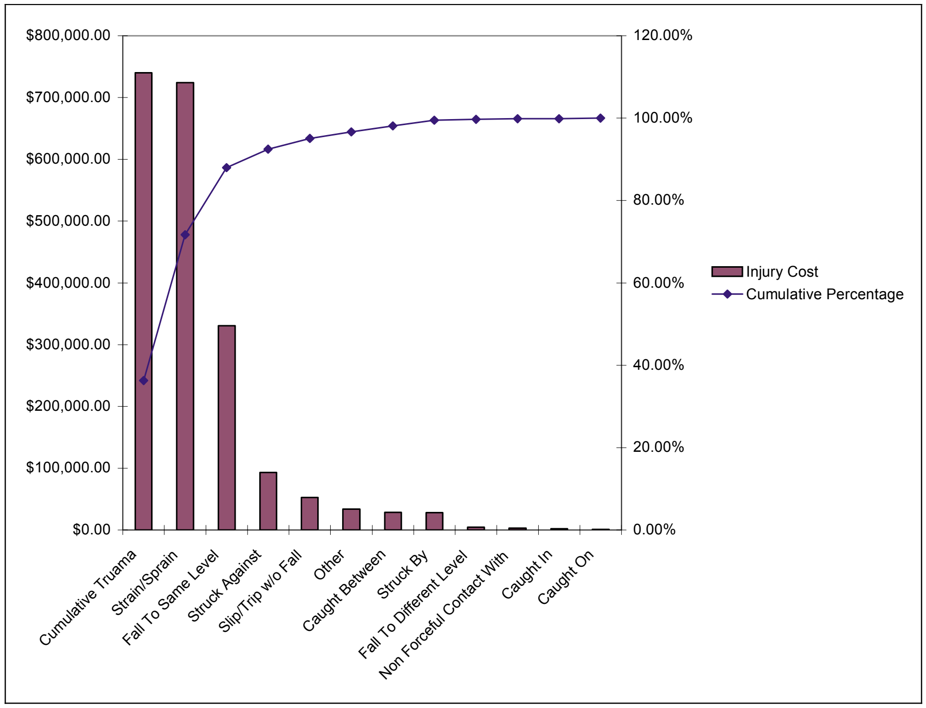

Figure 4. Pareto chart depicting costs by injury type and cumulative percentages for the year 2000.

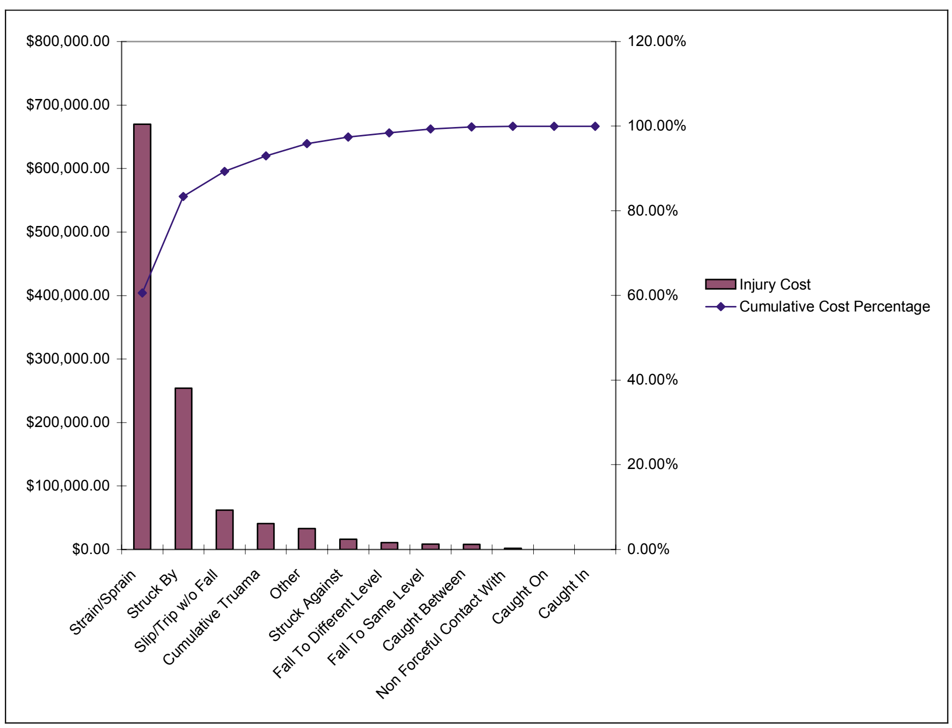

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Figure 5. Cause and effect diagram outlining root causes for strains and sprains.

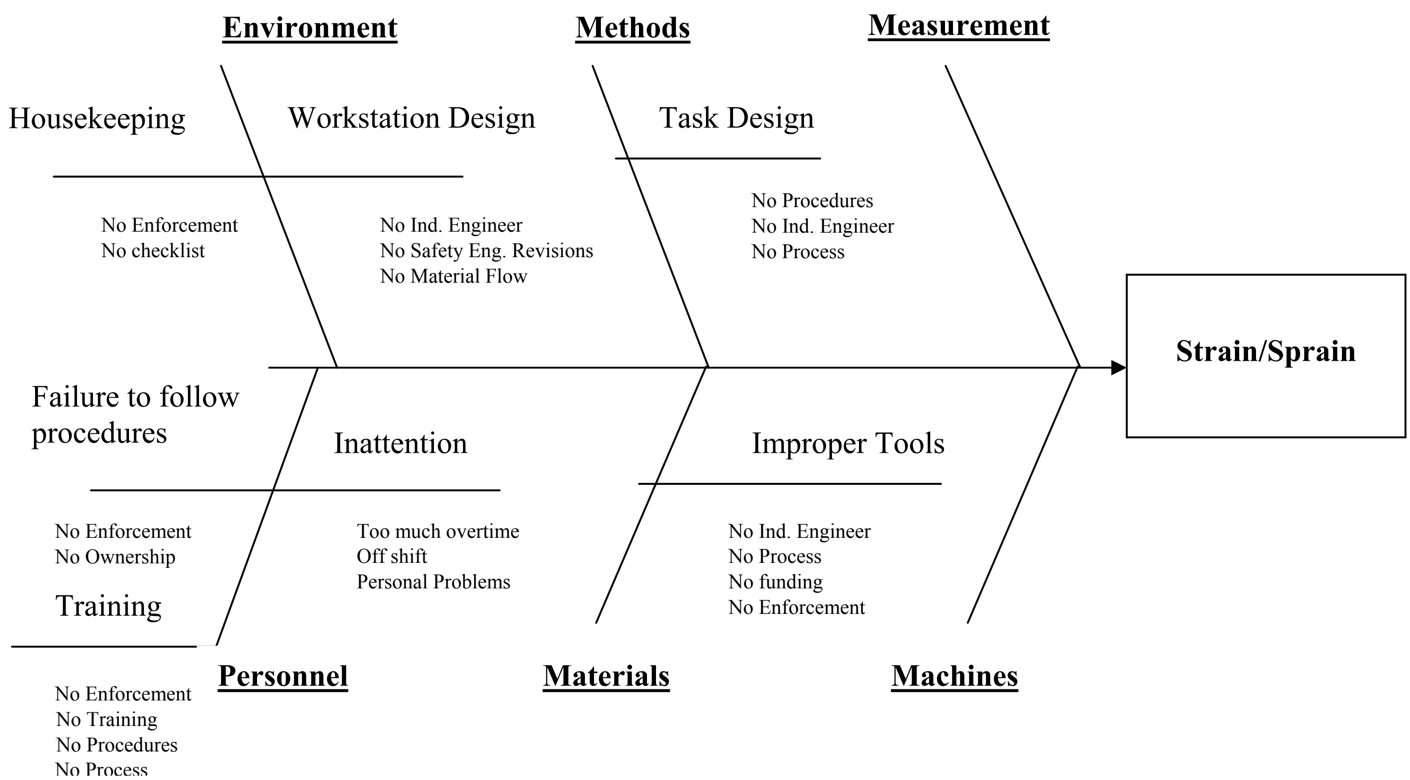

Figure 6. Cycle model for teaching and learning process outcomes.

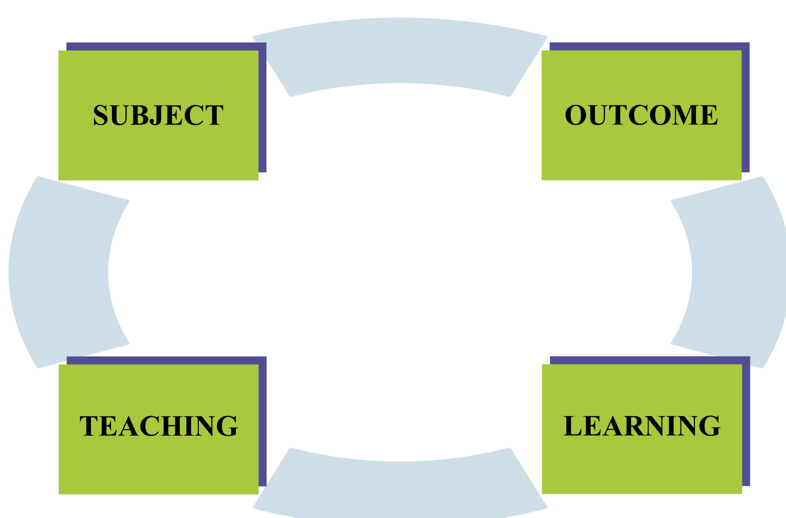

Figure 7. Industrial Safety Syllabus.

Industrial Safety
Lecture #1 • Health and Safety Movement, Then and Now • Development of the Safety and Health Function
Lecture #2 • Accident Investigation and Bookkeeping Requirements
Lecture #3 • Workers' Compensation
Lecture #4 • Texas Workers' Compensation Commission
Lecture #5 • ***Safety Metrics*** • Concepts of Hazard Avoidance: 3 E's of Safety Plus One
Lecture #6 • Impact of Federal Regulation on Industry: OSHA
Lecture #7 • Americans With Disabilities Act • Workplace Violence
MID-TERM
Lecture #8 • Health and Environmental Controls • Material Safety Data Sheets & PPE
Lecture #9 • Air Pollution • Noise Pollution
Lecture #10 • Fire Safety • Flammable and Explosive Materials
Lecture #11 • Confined Space Safety • Lockout/Tagout
FINAL EXAM

Figure 8. Quality Assurance Syllabus.

Quality Assurance
Lecture #1 • Definition of Quality Terms • Total Quality Management • Key People in Quality
Lecture #2 • Introduction to Variation & Statistics
Lecture #3 • The Normal Probability Distribution
Lecture #4 • Problem Solving: The Seven Tools of Quality • Safety Metrics
TEST I
Lecture #5 • Introduction to Control Chart Concepts • Variable Control Charts • Process Capability
Lecture #6 • Precontrol Charts • Individuals & Moving Range (X and MR) Charts • Attributes Charts
Lecture #7 • Permutations & Combinations • Probability & Interpreting Control Charts
TEST II
Lecture #8 • Lab Lectures
Lab Activities Begin • Class Meets in Laboratory for Next Two Weeks
Lecture #10 • Parallel and Series Reliability • Life Testing, Bath Tub Curve • Exponential Reliability • QS 9000 and ISO 9000
FINAL EXAM