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

By Dr. John E. De Leon

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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 indus-
try. Its wide applications range from studying behavior patterns in clinical psychology (Pead & Wheeler, 1995; Hantula, 1995) to analyzing incidents associated with packaging and transpor-
tation of hazardous materials by the US Department of Energy (2001).

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

Cross-functional Curriculum: Ini-
tializing the Experience
IT students are expected to work in in-
dustrial environments comprising myri-
ad 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 chal-
lenge by noting, “Industrial Technology
faculty and students need to understand
the connections and linkages among a
wide variety of business and manage-
ment concepts to better prepare them-
seals to succeed in the 21st century”
(p. 2). Hence, the role of cross-func-
tional education becomes increasingly
important in preparing IT students en-
tering 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 ap-
prehenships” (p. 2) within the frame-
work of existing safety and manufac-
turing 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
control programs” (p. 2). How-
ever, they do not incorporate discussion
on safety metrics in their thesis. Con-
sequently, 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 curricu-
lum. The course descriptions are:

Quality Assurance
A course designed to explore the vari-
ous aspects of industrial quality and
process control from a Total Qual-
ity Management (TQM) perspective.
Statistical methods used for analyzing
quantitative and qualitative data will
be addressed. Inspection tools and
methods for measuring product char-
acteristics 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. Criti-
cal 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 rel-
evant material that, if used effectively,
can excite students to new levels of un-
derstanding and appreciation. To that
end, it was the author’s intent to obtain
real-life injury data that could be sta-
tistically manipulated to determine an
organization’s safety performance. Op-
erating under the premise of contextual
learning (placing learning objectives
within real-world applications), the
company identified for the study rep-
resented one to whom students could
relate. The semiconductor industry was
a logical choice to target because of its
geographical convenience to the Uni-
versity and also because of the micro-
electronics-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) fur-
ished data was to be exclusively used
for educational purposes. Two years
of injury reports and workers’ com-
penstation 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 perfor-
ance expectations were being met.
Data analysis produced a snapshot of
the organization’s overall safety perfor-
ance. However, the resultant quantity
of information was so voluminous to
be useful for instructional purposes. It
was necessary to condense the find-
ings into a manageable and meaningful
education module.

Janicak (2003) observes that his-
torically control charts have been used
extensively to evaluate loss and acci-
dent information. He critically points
out that the more informative charting
techniques (i.e., cause and effect dia-
grams, Pareto diagrams) are “used only
to a limited extent” (p. 3). Moreover,
these two applications are user friendly
and fairly easy to construct and inter-
pret. These two techniques have been
preferred as the means for accomplis-


ing 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.

References

![Figure 1. Pareto chart depicting injuries by type and cumulative percentages for the year 1999.](image1)

![Figure 2. Pareto chart depicting injuries by type and cumulative percentages for the year 2000.](image2)


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

**Figure 6.** Cycle model for teaching and learning process outcomes.
### Industrial Safety

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

**MID-TERM**

**FINAL EXAM**
### Quality Assurance Syllabus

**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**