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Details on the Eindhoven programs as well as the universities that were surveyed can be obtained by writing or emailing the author.

2. Simulation in Employee Training Achieves Risk Management

by Phillip S. Waldrop

"The importance of overcoming basic ignorance and fear and developing a common understanding of capabilities, limitations, and implications is critical to quelling worker and management fears" (Giffi, Roth, & Sean, 1990, p. 321).

To better establish the context for the simulation and its importance, a brief review of the factors leading to changes in production, some specific changes, and the change effects upon workers are discussed. Presented here is a case study of how the top management of one small company sought to communicate with its employees. The goal was to demonstrate effectively with a hands-on instructional technique the problems and limitations inherent in the traditional approach to manufacturing, in contrast with the merits of other new approaches, which tend to create some turmoil during their adaptation and implementation in the firm. The instructional technique described here is available to other firms and for use in academic programs in which technology and management professionals are prepared. The simulation effectively, clearly, and meaningfully teaches the ideas and benefits underlying the new approaches.

FACTORS LEADING TO CHANGE

In recent years much of the published material has focused on the benefits of methods and techniques that are often lumped under the category of "World Class Manufacturing." These imply that to survive in a very competitive global economy, companies must effect improvements in key areas of cost, quality, and scheduling. Two common approaches that address these key areas are cellular production organization cells with teams and just-in-time (JIT) production operation.

Such approaches are "buzzwords" in today's literature, the meanings of which are fairly well understood by those who have studied them. They are likely to be less understood by many who are impacted by them in their workplace. The changes suggested by the buzzwords involve breaking away from traditional and familiar methods that have provided the fabric of the company's internal "culture." Very large and prominent industries have often led the way in application and implementation of such approaches because they have the depth of resources to plan, invest, and manage such major changes. Yet the vast majority of manufacturers in and beyond the United States are small companies that may face proportionately greater risk if their efforts to effect change do not succeed. A 1994 survey of advanced manufacturing efforts, conducted by the Computer and Automated Systems Association of SME, found that 75% had failed, and that efforts to re-engineer business processes failed 80% of the time (Owen, 1996). A critical element of risk is "user acceptance" of new methods and tools: members of the workforce must understand and accept the goals, objectives, and potential benefits of what is likely to be a major change in their working environment and jobs. Acceptance of change may be particularly important as team concepts such as empowerment in decision making are introduced.

COMPETITIVE DEMANDS, CELLS, AND JIT

Cells and JIT are related to what may be called time-based competition. In the past, competitive emphasis was on low price; after World War II, the Japanese, seeking economic recovery, first entered the U.S. market with low-priced goods. Under the influence of such persons as J. Edwards Deming, there were shifts toward higher quality, a competitive thrust which is still a significant area of study and influence on change for competitive survival (Deming, 1986; Hayes, Wheelwright, & Clark, 1988). Industry constantly strives for lower internal costs in order to meet market price demands, and product quality has generally improved and continues to be refined in all types of products.

Today, far more sophisticated consumers expect both good price and quality. While still striving for continuous improvement of cost and quality, industry now faces major competitive pressure in regard to time-to-market. From product concept to presence on the store shelf or showroom floor, product development and production timelines are shrinking (Wantuck, 1989). Firms that fail to get new products into the consumers' view quickly will typically lose significant market share to their competitors (Steudel & Desruelle, 1992). Product competition today also involves pursuit of consumers through introduction of new products and offerings of many variations to match the varied preferences of a diverse consumer base.

Such dynamics have negated much of the old economy-of-scale basis for production operations, and flexibility is now a key driver. Methods such as concurrent engineering help to reduce the design timespan, while in the production area cellular organization of the factory and JIT processing seek to get the product built and out the door (Giffi et al., 1990).

Historically, production operations and facilities were organized by process type (e.g., machine shop, pressworking, assembly, and finishing). However, the cellular approach involves organizing the plant into smaller process areas, typically based on a so-called group technology arrangement. Parts and/or assemblies are processed in dedicated work cells designed for efficiency by having their resources focused on a narrowed range of similar product/process combination (Nolan, 1993).

JIT operations are primarily focused on reduction of inventory, with major benefits including reduction of investment in raw materials, work in process, and finished goods; reduced potential for goods spoilage or obsolecence; and smaller batches of work-in-process in which quality problems may hide (Kobayashi, 1990).

CHANGE CHALLENGES THE WORKFORCE

The major changes involved in converting from a traditional factory layout to cells, and from narrow-scope traditional job descriptions to the multiple responsibilities and team decision making typical of cells and JIT, can affect the attitudes, morale, and performance of employees, supervisors, and managers. For example, to more uniformly balance workloads among team members within a cell, instead of simply being a lathe operator, a person may be trained on several or all of the process skills needed in the cell. Individuals may be trained to inspect their own work and their cell co-workers' work, and also to manage their own processes. This represents a major shift in the scope and nature of responsibility. Years ago, employees tended to complain of boredom from repetitive operations, while more recently "studies indicate that workers tend to feel threatened if they have to make decisions on the job"(Amrine, Ritchie, & Moodie, 1987, p. 366).

Management must consider and balance human factors along with technology, preparing workers for impending changes. Nyman (1992), in discussing flexible manufacturing cell (FMC) implementation success, stated that "it's been proven that ignoring people does not produce good results. Some technically sound FMCs have been outright failures because the needs of people were overlooked. As a consequence, time and money in quantity should be reserved for communicating plans, soliciting input, training, retraining, team building, managing change, and problem solving" (p. 39). It is human nature to enjoy stability; the process of change and the unknowns of the future tend to be a barrier to acceptance and morale. What must be expressed by management and understood by the workers "is the vision of what the organization is about and what its goals are" (Hayden & Johnson, 1996). Given the major effort and investment involved in planning and implementing factory conversions, it is essential that all employees be provided proper information and insight into the goals, objectives, and subsequent benefits of the future situation. But to simply throw out buzzwords such as *cells* and *JIT* is not sufficient. Management needs to communicate the benefits to be derived from the dramatic change so that people can recognize it at a cognitive level that will allow acceptance and, thereby, reduced risk.

THE SIMULATION

This was the challenge that faced Santech, a small firm in Fort Worth, Texas. Its president, Michael Deese, has been very successful in refocusing his firm's product line to what it does best in a "niche," and then recreating the facility and operating structure to maximize the improvements in cost, quality, and scheduling. He decided that to get his employees to understand and accept (as opposed to simply being told about) the forthcoming changes, a simple simulation exercise would be appropriate and effective; he developed a simple tabletop simulation package that has proven highly successful with Santech employees. This reporter observed the exercise on-site at Santech and subsequently procured a simulation kit for use in the industrial management/manufacturing program at Georgia Southern University.

The simulation exercise involves six participants and a facilitator. Additional audiences or trainees may effectively learn through observation of the activities. A kitted set of materials contains all items required, including instruction sheets for the facilitator and participants. Facilitator instructions include, for each simulation phase, statements of quality objective, logistics arrangements, guidelines for the exercise, description of expected changes from the prior phase, and lessons to be learned.

A key component is a chart (Figure 1) used to record the observed productivity indicators from each completed phase of the simulation, including:

- Time to assemble the first plane off the line (cycle time),
- Total good planes produced,
- Total planes for rework,
- Total planes in WIP, and
- Total planes scrapped due to defects.

Six Minute Run	Total Good Planes	Total Planes For Rework	Total Subassy For Rework	Time For 1st Plane Done	Reasons for Difference
#1					
#2					
#3					
#4					
% Change 1-4					

Figure 1. **Observed productivity indicators.**

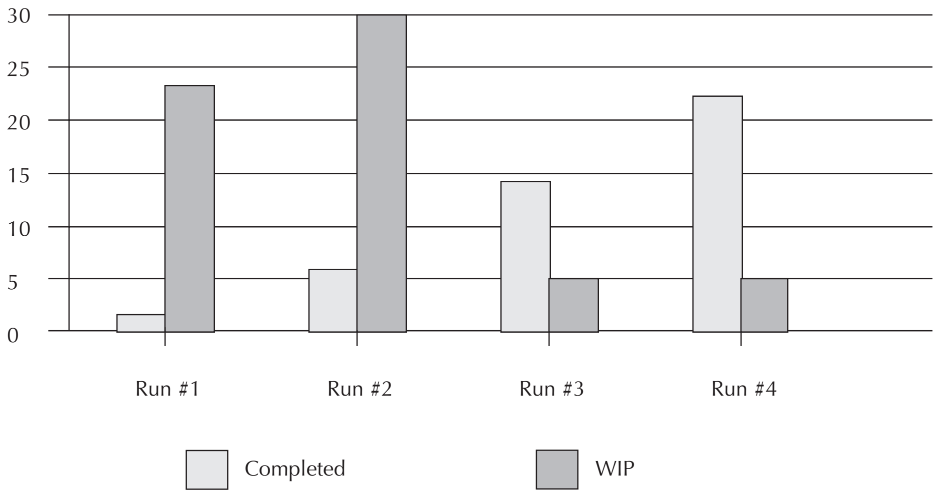

Figure 2. **Throughput.**

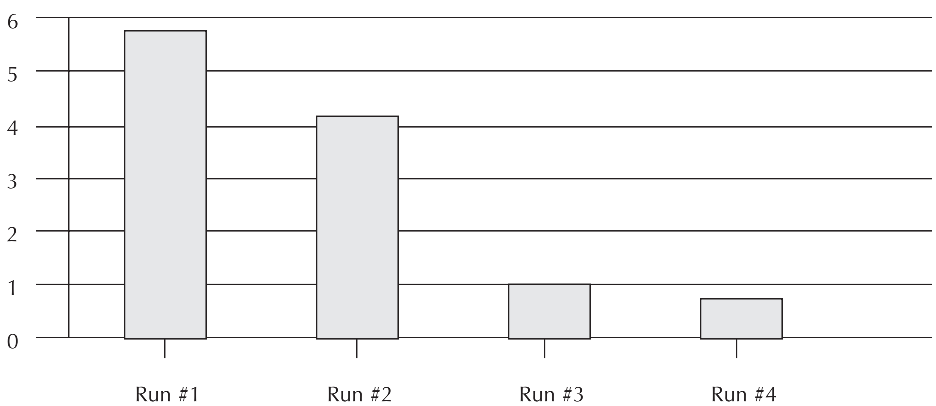

Figure 3. **Cycle time (first completion).**

The simulation activity begins by providing an oral introduction to the activity and its purpose. Then, participants are arranged around a large table in an indirect order of tasks—comparable to the often illogical factory floor pattern of traditional process-oriented production—with product materials stored in a "warehouse" so that workers must make periodic trips away from their work stations to retrieve materials in small lot quantities. The task is to assemble LEGO© blocks into the form of an "airplane," initially using a continuous "push" work flow with an inspector at the end. A practice run gets the learning curve out of the way, then a production run begins. Part way through, a quality problem is announced, and the WIP is set aside as scrap and/or rework. Production resumes and then eases at the end of a timed period totalling six minutes. The resulting productivity data is collected and displayed on the chart. Completed and WIP product materials are then broken down and replaced into their storage area in preparation for the next phase.

A few changes are introduced for the second phase of the simulation. Workstations are re-arranged more closely and in a logical sequence to simulate a cellular arrangement, with all materials close to the workstations. Production is still in a "push" mode, and the quality interruption is repeated. Final inspection remains the same, but airplanes are now assembled in batches of five. At the end, data is recorded, revealing that the changes have yielded an increase in throughput, but more scrap was produced because production increased without a reduction in WIP.

The additional changes in the third simulation phase are significant. Batch lot production is changed to one-piece flow, and a "pull" system replaces the traditional "push" approach. The workers now are not to produce assemblies unless the queue for the next workstation is empty, and then they produce only one. Finally, workers are "empowered" to inspect their own work. In this way the quality is inspected several times as it progresses, rather than at the end. Observed results from this run will be that throughput increases further, but more importantly WIP and scrap decrease substantially.

The fourth and final phase introduces a more flexible cell workforce that is, in part, retrained to handle multiple tasks that are assigned to reduce the differences in workload of each person, thus providing a "balanced cell." Production throughput increases even further, with a stable WIP and further reduced scrap.

RESULTS

The data shown in Figures 2 and 3 typify the results of this simulation exercise. They clearly illustrate the limitations of the traditional layout and push flow in contrast with the benefits of the incremental changes that lead to the one-piece flow, pull system with workers who are able to share a balanced load and inspect their own output.

With only a simple, brief hands-on simulation exercise, employees (and students) learn the true impact of "world class buzzwords" in direct, quantifiable terms. The benefits derived from the changes are obvious. As desired by Santech management, employees who might otherwise be "clueless," nervous, and concerned about the changes in their company and jobs can understand the objectives and need for change. Morale at the firm is good and most employees enthusiastically accept the changes and willingly participate in implementing them. They and management became more keenly aware that (a) significant changes in the manufacturing environment are necessary and (b) that it is critical to communicate effectively to the workforce in order to reduce the risk of failure in these changes. In implementing technical change, it is essential to remember that industry is not technology: it is people using technology. Productivity gains cannot be made while ignoring the human factors. Members of upper management in industry can effectively demonstrate to their operations managers, supervisors, and hourly personnel why the status quo is unsatisfactory by utilizing methods such as the Santech simulation, and thus motivate them to accept and become proactive in implementing the necessary cultural changes in moving toward world-class competitiveness.

Mr. Deese of Santech has demonstrated the simulation exercise to participants of a small business development seminar series conducted at the ARRI (Automation and Robotics Research Institute) facility of the University of Texas/Arlington. He is also making a packaged kit including all materials and documentation available. Technology managers and technology faculty may obtain a well-developed, industry-proven tool to convey difficult "book" concepts at a reasonable cost. Information can be obtained from the author.

"Dissatisfaction with the status quo must be felt at all levels of the organization. This gives people the impetus to change. It is not sufficient for management to mandate change" (Weddle, 1994).

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3. Computer Simulation and Virtual Reality Applications in Technology Studies

by Xueshu Song

This describes a program designed to teach welding and a research project to assess its effectiveness. The discussion that follows draws implications and conclusions concerning this instructional innovation.

Welding as an industrial technology is vital to our national economy. Experts estimate that welding is involved in about 50% of the GNP (Gross National Product). More than a million people work in 60 welding-related occupations in the United States. High tech-oriented welding procedures have been introduced by industry in recent years. The many dimensions of metallurgy, physics, mechanics, chemistry, geometry, economics, management, and psychology of welding epitomize the interdisciplinary nature of state-of-the-art modern technology studies (Song, 1995a). A welding technology curriculum, either on its own or as part of the industrial technology curriculum, is taught throughout the world.

Welding activities, however, are potentially hazardous for students due to exposure to dangerous fumes, noise, and radiation and the risk of electric shock. These hazards cause concern among students. Institutions have to take extra safety measures because most students have no experience with these processes. Most educational institutions do not possess electronic beam welding, laser welding, or explosive welding equipment because of monetary and safety constraints. There is a consensus among government, industry, and the education communities that it is imperative to find more effective, more efficient, safer, and less costly ways of educating and training the workforce in the welding industry (Song, 1995a).

The recently completed Welding Lab on Disk (WLOD) project (Song, 1996) was a further development of the WLOD system based on the original modules conceived and developed by Song (1991). The primary objectives of the