THE NEED FOR WORKER TRAINING IN (AMT) ENVIRONMENTS

Faisal Hasan

ABSTRACT

With the advent of advanced manufacturing systems new modifications have been introduced in the working environment. Several areas including economics as well as engineering have benefited a lot from this drastic change. Similar to that of the technical aspects, the human factors has played a key role in the advancement area. And these factors have resulted in the fructification of many new systems. Hence, prior to the design of a flexible manufacturing system, the technicians' management and the unions should be aware of the entire alternative to design the same.

Key words- Advanced manufacturing technology, flexible manufacturing system, manufacturing organizations, Manufacturing systems, worker training, manufacturing organizations

01. Introduction

The international globalization of the World markets for manufactured goods, particularly consumer goods, has placed an emphasis on nations to improve manufacturing productivity. This need to improve productivity is further prompted by a potential loss of competitive edge in the global marketplace. The market competitiveness and efficiency of any nation is primarily dependent upon the economy, reliability, quality, quickness, and ease of its manufacturing processes and the resulting quality of outcomes (products). To a major extent, the skills of the workforce determine the effectiveness and the efficiency of the process of manufacturing and the quality of goods produced. And yet, there is a severe lack of standardized and consistent worker training programs for skills needed by workers in modern manufacturing organizations. This review paper shows that there is a dire need to train workers in manufacturing organizations and thereby improve the overall effectiveness and efficiency of such organizations. As technology changes, so do the skills workers need. In order to compete successfully in the global manufacturing organizations must aim at training workers in skills necessary to produce quality goods. (1999 Elsevier Science B.V.)

Historically, the process of manufacturing goods has evolved from craftsmanship to a highly organized factory system. The factory system itself has changed dynamically from mechanized powered systems to the present day trend towards application of advanced manufacturing technology (computerized design, planning, and manufacturing tools such as CAD, CAM, MRP, etc.). Paralleling this evolution have been dramatic changes in the skills required of the human component of the system. Such improved skills are needed in both cognitive and psychomotor areas. Although recent developments in technology have made very significant contributions towards improving productivity in the manufacturing sector, there has been an increase in the skill demands placed on the human as an integral component of the continually evolving work system. For example, the introduction of automation has increased the cognitive skill demands, and in many cases, it has not addressed its primary objective of decreasing the level of physical demands placed upon workers. Nevins and Whitney (1989) state that the drive to automate has led to automating simpler activities, leaving difficult tasks for humans to perform.

Further, the changes in the organizational structure, workplace philosophy, and the market demands for product mix, volume, economy, and quick response times have placed additional burdens on the skill demands of the entire workforce, ranging from the hourly worker to the professional manager. As a result, a member of the workforce in a modern manufacturing setting frequently has to work as member of a team and is required to make decisions while being confronted with a continual flow of vast amounts of information. The worker must be able to make effective use of the tools of modern technology. Members of work teams have been relegated to the roles of system monitor and controller as opposed to routine performers of a task. Organizationally, changes in the expected role of the human component in a manufacturing environment demand that workers possess a wide variety of skills at various levels.

Manufacturing may be viewed as the application of skills resident in humans to produce marketable goods of benefit to society. The skills necessary to produce these goods are acquired by a person (in this context, the worker) by developing basic abilities inherent in the individual. The process by which such inherent abilities are developed into job specific skills can generally be considered as training.

Currently, most manufacturing organizations train their employees in various ways, using different means, and achieving different levels of proficiency. Rarely does one find standardized and consistent training programs to develop worker skills; optimal training programs are not generally known. This leads to workers acquiring industry- or company-specific skills, often leaving them with only a few transferrable skills. It is well recognized that the failure of many companies to transition to modern competitive manufacturing organizations is primarily due to their mismanagement of human resources (Ettlie, 1988; Majchrzak, 1988). Specifically, many organizations have failed to upgrade worker skills to levels compatible with advanced manufacturing technologies (Butera and Thurman, 1984; Gerwin and Tarondeau, 1982; Shaiken, 1984; King and Majchrzak, 1996). It has been shown that variables such as comprehensive training are essential to human resource management practices, particularly in advanced manufacturing environments (Walton and Susman, 1987; Commission on the Skills of the American Workforce, 1990; Hitt et al., 1991; Perry, 1991; Snell and Dean, 1992). A number of investigators have shown that worker skill levels are a direct determinant of levels of quality performance (Flynn et al., 1995; Hackman and Wageman, 1995). It is also reasonable to suggest that investments in human resources should keep pace with the changing technology particularly if the workers are to take responsibility for quality, productivity, and customers (Majchrzak and Wang, 1996).

The present climate contains changing industrial trends (e.g. downsizing of the organizations), renewed social policies and governmental regulations (e.g. the Family Leave Act and the Americans with Disabilities Act), and the changing demographics of the workforce (e.g. the ageing of America and its influence on the nation's competitiveness) US Department of Labor, 1989; Mital et al., 1993 andMital, 1994a; Hall and Mirvis, 1994). It is essential that workers in manufacturing environments receive training to meet the changing market needs as reflected by the demands placed on their skills.

As the brief discussion above points out, the quality of workers' performance is directly tied to their skills. Further, many firms have yet to make serious investments in human resources, particularly when it comes to upgrading worker skills to levels that are compatible with the needs of advanced manufacturing technologies. The purpose of this review paper is to focus on the need for worker training in Advanced Manufacturing Technology (AMT) environments. In this review paper, our focus is on manufacturing and the need for developing and evaluating generic, consistent, and standardized, on-site industrial training programs in manufacturing industry.

02. Literature Review

Manufacturing systems are considered essential by most nations for the creation and propagation of wealth, and for improving the standard of living of its people. Estimates show that developed countries, such as USA, Japan, Germany, and other nations in the Pan-Pacific region, such as Taiwan, South Korea, Singapore, and Hong Kong, have a manufacturing base comprising at least 20% of their gross domestic product which provides for at least 30% of their traded goods. Given the extent of manufacturing activities carried out in many different countries in the World, the design and operation of manufacturing systems assumes tremendous importance from the perspective of making nations competitive. The ability to compete is vital for contemporary manufacturing due to the globalization, or internationalization, of all aspects of product manufacture (quality, product variations, labor, technology, markets, etc.).

In the United States, the issue of designing and operating manufacturing systems that can retain the global economic advantage is a major concern to industry leaders, academic researchers, Congressional policymakers, and officials in the Federal Government. The Report of the President's Commission on Industrial Competitiveness (1985), and research reports generated by the National Academy of Engineering (1988), the National Research Council (1990), and the National Science Foundation sponsored workshops conducted at the University of Cincinnati

(Mital et al., 1994b; Mital, 1995, 1996) demonstrate the seriousness of this concern. Some of these reports also contrast the relative importance of advanced technology with human resource-based technology and high- light the fact that, among countries with a large manufacturing base, the United States no longer dominates in the creation of new and advanced technologies. According to Farnum (1987), the worldwide share of American advanced machine tool production in 1987 dropped to 7.8% as compared to Japan's share of 20.5% and Germany's share of 19.9%. Also, in advanced machine tool exports, the US share was low (4.4%) compared to Japan (20.8%) and Germany (22.6%). Further, many countries now have the scientific and technological infrastructure to create new technologies. What then must make a positive difference to the United States industrial competitiveness, these re- ports conclude, is the development of a skilled human resource base.

There is now a broad consensus among the members of various academic, industry, and government institutions that manufacturing organizations, in order to be competitive in the global market, must be able to produce wanted and needed products that have a very high quality, are reliable and economical, and can be produced easily and quickly. It is also realized that the development of a highly skilled human resource base in manufacturing is vital if these manufacturing organizations are to retain, or regain, their competitive edge in the global product market. In fact, understanding the personal preferences and interactions between the individuals within the organization will be the key to accomplishing this change quickly and effectively (Rajan, 1996a). Some of the issues pertaining to the role of humans in a globally competitive manufacturing organization have also been discussed by Mital (1997). It is worth noting that many industries, such as IBM, Xerox, and General Motors, have begun to, or are planning to, reintroduce humans as a key elementin their manufacturing operations, emphasizing the importance of individual personal preferences and interactions in teams for change towards competitiveness. Many of these industries, for example Xerox, have been ardent supporters of complete automation in the past and now advocate human in- the-loop control, particularly for cognitive functions, emphasizing, in general, the need for a highly-skilled manufacturing workforce capable of interacting with AMT.

02.01. Evidence of human necessity

The argument that humans are essential, and will remain essential, in manufacturing environments has been put forth by Mital et al. (1994c,d). Their arguments are based on economics, human performance, and cybernetics (system and task factors). To summarize, the fact is that fully automated factories are not yet viable for technical and economic reasons except in a very few special cases. Furthermore, for cybernetic reasons, it is likely that full automation will be a suboptimal solution for manufacturing organizations for the foreseeable future compared to hybrid systems combining people, machines and computers in effective partnership. The importance of people as components for control and innovation in manufacturing systems is recognized worldwide (Brodner, 1985, 1987; Corbett et al., 1991; Hockley, 1990; Hammer, 1992; Grant et al., 1991; Gill, 1990; Kidd, 1992; Kearney, 1989; Kohler, 1988; Nonaka, 1991; PA Consultants, 1989; Porter, 1990; Senehi et al., 1991; Sinclair, 1986, 1992; Wobbe, 1992; Yamashita, 1987; Yoshikawa, 1992).

Further, evidence exists that hybrid systems will continue to dominate manufacturing. The Law of Requisite Variety (Ashby, 1962a,b; Brehmer, 1988) states that for any system to remain under control, the controller of that system must be able to absorb the entire range of inputs that may affect the system (i.e. the system or the control process must be at least as complex in its behavior as the system it is trying to control). It is difficult for any automated system to deal with a broad range of inputs from the different environments influencing manufacturing without extensive programming. Given that a manufacturing organization is an open system (i.e. is affected by its physical, commercial, legal and social environment as well as its own environment) then the control subsystem must be able to remain in a stable state. Quite apart from the nature of such inputs (most of which exist in human-compatible form, but many of which could be made computer-compatible), there is the content of this input. Within the organization, the decisions to be made vary in importance, and hence the type of information required for decision making also varies (Rajan, 1996b). The information content varies from very low level of detail to very high level of detail. It is difficult for any automated system to deal with high level information, and make the necessary deductions and other inferences without an enormous investment in background knowledge stores. Furthermore, the unexpected nature of some of the inputs will require human-like intelligent control procedures, unlikely to be available in the foresee- able future, to be generated and implemented by automated systems. This discussion leads to a critical difference in human control and automation of manufacturing systems. Humans are capable of digesting high level information for decision making or goal-directed task performance along with using low-level information in decision verification;

whereas, the limited capabilities of expert systems/ artificial intelligence in manufacturing systems is relegated to data-directed performance or decisions.

Secondly, there are the system improvement, sys- tem monitoring, and maintenance roles to be per- formed within manufacturing units. Again, these roles require human-type intelligence, and frequently great manipulative skills for their performance. It is difficult to see how such roles could be performed automatically. For example, the use of teleoperators (human remote controlled robots) in hazardous manufacturing tasks has proved, in many cases (Clarke and Kreifeldt, 1984; Bullinger et al., 1987; Parsons and Kersley, 1982), to be more economical and productive than the use of telerobots (semi-autonomous robots) requiring elaborate sensor arrays and extensive programming to match human sensory/perceptuo-cognitive capabilities.

It should be evident, therefore, that people will remain a necessity in manufacturing organizationsfor a long time to come. There can be no doubt that many of the functions currently being performed by humans will be taken over by automation, and indeed in many cases this is to be welcomed (in general, these functions are those that are fairly well proceduralized, require little creative input, and permit algorithmic analysis). The functions that are not automated will be those requiring cognitive skills of a high order: designing, planning, monitoring, exception-handling, failure-mode recovery, and so on, and must still be performed by humans. Some manufacturing researchers and practitioners, in fact, openly admit that the human is the most versatile worker, and products and systems redesigned with this fact in mind can tremendously reduce cost while improving quality (Coleman, 1988; Boothroyd, 1990; St. Charles, 1990). However, depending upon how we automate manufacturing, be it allocating a set of coherent cognitive functions to the human involving active decision making in process control, or relegating the human to the role of manager of incoherent cognitive tasks involving passive (process intervention) decision making, which technology cannot account for, the benefits of the versatile operation may or may not be realized.

02.02. Lack of worker skill development

While there has been a virtual proliferation of enabling technologies for manufacturing, very little attention has been paid to the integration of hu- mans in advanced hybrid manufacturing settings. Integration of humans is especially important as there is overwhelming general evidence (resulting mostly from reactions to introduction of advanced technology) that workers are unable to cope with changes in manufacturing technology, with the present job skills they possess.

According to a re- port of the Commission on the Skills of the American Workforce (1990), there is `...considerable evidence that the current skill level of the industrial workforce leaves the United States less able to derive competitive advantage from new technologies than our competitors...a. According to Adler (1991), there is a general trend towards higher skill requirements among manufacturing workers due to speed of the automated equipment. Further, according to Adler, since the role of the human is becoming supervisory in nature, and because of the nature of the computer-controlled technology, there is an increasing demand on maintenance skill requirements (`traditional mechanical, hydraulic, and electrical skills supplemented by electronics expertise). Bushnell (1983) and Helfgott (1988) re- port that manufacturing firms adopting computer- based technologies are upgrading selection criteria for maintenance jobs to reflect the changes in skill requirements with changes in technology. In addition to maintenance skill requirements, operator ability to perform passive-decision-making in supervisory control scenarios (i.e. determination of whether to intervene in the process control) is be- coming increasingly important. Companies have realized through empirical research that training and operator experience significantly affect human monitoring performance in discriminating among information sources and deciding when to take- over manual control from automation (Moray et al., 1982).

Replacement of workers appears to be a way for companies to transfer the necessary skills from the open market to their environments. The workers who are laid o!, perhaps due to a lack of skills, in many cases, are unable to find jobs or jobs that are comparable to their previous jobs in terms of salary and benefits. A recent US Department of Labor report chronicled by TIME magazine (25 October 1993) stated that only 20% of the laid-off workers are able to find jobs that pay up to 80% of the earnings of their former jobs. The surprising fact is that these workers have undergone retraining. The retraining aid in acquiring the skills AMT industries need but did not serve to secure new jobs offering competitive salaries. On a more basic level, the results of a recent survey, carried out to assess the impact of programmable automation on the occupational structure in durable goods manufacturing, showed that there was a need for an increase in basic skills in mathematics, and verbal and writ- ten communication among workers (Jacobs, 1994). These general findings are in agreement with the surveys conducted by the United States Department of Labor (1993a), and the Hudson Institute (Johnston and Packer, 1987). What is disturbing about these conclusions is that they are based onsurveys and general questionnaires administered after the introduction of advanced manufacturing technologies. Therefore, inputs to such surveys are, at best, reactive, indicating that consideration of the human element in manufacturing is more an afterthought than a planned one. This observation is further supported by the fact that scientific studies analyzing the role of humans and the integration of humans in hybrid manufacturing settings, using advanced technology, are few and far between.

There is now a general consensus among policy makers and engineering researchers that advanced manufacturing technology is leading to a redefinition of workplace skills. There is a dearth of industrial scientific studies (studies on skill requirements for effective human performance, studies on training including the types of training such as cross-training vs. retraining, mode of training delivery, etc.) clearly defining the role of the human in hybrid, and possibly fully automated, manufacturing systems. Such studies are especially essential, not only in light of the advances taking place in manufacturing technology, but also in considering the changing demographics of the US workforce. Therefore, it is worthwhile discussing what training accomplishes and how it benefits the workforce.

03. Benefits of training

Overall, training leads to acquiring new skills and/or improvements in existing skills (Carnevale and Goldstein, 1990). These, in turn, lead to two distinct economic benefits: (1) improvements in individual choices and earnings, and (2) cost savings for the organization. According to Carnevale and Goldstein (1990), on the average, about half of one's lifetime earnings are driven by learning in school and on the job. People with low skills, or skills not needed by employers, have limited choices and low earnings (Lillard and Tan, 1986). Increasingly, we are encountering situations where people with low or unneeded skills are unable to "nd employment that will maintain their standard of living, or are being forced to accept jobs that result in a substantial lowering of their earnings. Since the skills learned on the job complement educational experiences and lead to individuals' having more choices, on-task training is critical.

Economic benefits of training for organizations include significant improvements in productivity (through improvements in quality, reduction in scrap and waste, reduction in throughput time, greater flexibility to respond to needs, etc.), and a competitive advantage of employers and the nation as a whole (e.g. Denison, 1984; Mincer, 1988; Carnevale and Goldstein, 1990). The United States Department of Labor (1993b) has reported that formal worker training introduced in 180 manufacturing firms in the United States increased overall productivity by 17% in 3 years when compared to industries that did not introduce any training pro- gram. The Department of Labor also reported that another survey of 157 small manufacturers observed a drop of 7% in scrap and an increase of 20% in the productivity of production workers. The economic benefits of training, thus, point out the necessity of introducing formal training pro- grams in manufacturing industry. Moreover, the greater the complexity of technology, the greater will be the training and human resource management needs.

03.01. Difficulties with existing training programs

A review of training literature reveals that the wealth of learning and training studies are confined to collecting data in laboratory settings, needs assessment, individual and cultural differences or deal with mathematical or behavior modeling of training (e.g. Bilodeau, 1966; Special Issue of Human Factors, vol. 27(3), 1985; Adams, 1987; Mayer and Russell, 1987; Campbell, 1988; Black et al., 1990; Park, 1991; Glencross, 1992; Felan et al., 1993; Stewart et al., 1994; Gilbert and Rogers, 1996; Volpe et al., 1996; Prislin et al., 1996). Analytically based training techniques have generally been confined to the military (e.g. Johnson, 1981; Travillian et al., 1993; Goettl et al., 1996). Reviewers, in general, have concluded that training theory and practice do not complement each other, and that research findings are not interpreted into effective training methods (Cannon-Bowers et al., 1991). Wexley (1984) stated that certain critical areas oftraining need systematic study which includes factors such as the organization, task and program design, individual differences for training strategies, and workplace factors affecting the transfer of training. In fact, very few research studies using systematic procedures for developing employee-training protocols have been conducted and validated within an industrial setting. Also, statistically designed experiments to test various training methods have not been formulated and evaluated within the workplace. Thus, there is a need to develop training protocols using a systematic procedure and conduct empirical assessments using these developed training protocols within an industrial setting to determine the effectiveness, efficiency, and productivity of training.

There is also the issue of the lifespan of learning for adults. In the era of rapidly changing techno- logy, ability to learn new things is more critical than experience or years on the job. The ability to learn is particularly critical for adult employees as employers tend to believe that workers who have been on a job for sometime have difficulty in adapting to new methods (Hall and Mirvis, 1994). The learning also needs to be holistic and systemic, and less linear (Senge, 1990; Bolman and Deal, 1991; Schein, 1992; Stacey, 1992; Fullan, 1993; Muncie and McQuillan, 1996). While significant work has been done on child learning (goal oriented), relatively little has been done in the area of goal- oriented adult learning (Tannenbaum and Yukl, 1992; Froman, 1994). Adult learning has implications for the development of comprehensive performance-based goal-oriented training programs. Many adult workers find themselves in a transition period, particularly in mid-career, and question and reappraise their life and career structure. In such periods, individuals may experience conflict between the motivation to learn, on the one hand, and perceptions, fears, and habits that block change, on the other. Any effective training program will need to consider employee needs, their motivation, career plans, etc.

Despite the economic advantages of training and the need to prepare the American workers for global competitiveness, training studies dealing with industrial applications, particularly those that are performed infield, are scarce. It is also worth noting that critical review articles dealing with the training issues are lacking (Howell, 1996). Workers in modern manufacturing environments not only need training in depth (level of proficiency in a skill) but breadth (different skills) as well (Jacobs, 1994). Moreover, these skills need to be updated and modified regularly as the technology changes. In contrast, the traditional model of industry training, if any, requires an apprenticeship, sometimes an extended one (e.g. 5 years) only at the beginning of a career.

At present, relatively few American industry workers receive training. Those trained, in turn, train others. A survey of auto workers at a General Motors assembly plant revealed that less than 20% of production workers received technical training, although nearly 83% received some form of training. A survey of contract labor in the US petro- chemical industry by the John Gray Institute (1991) revealed less than 33% of workers to have received company training upon entering the industry. Further, 20% of this same labor force reported receiving no on-going training throughout their employment. Also relevant is the question `How well current training programs works. This question has been partially answered at the Federal Government level. According to Senator Mike DeWine, the current Chairman of the Senate Labor and Human Resources Committee, there are over 160 different job training programs sponsored by the Federal Government. These programs are frequently not only duplicative; they are short on proven results. Such job training programs, considered essential to improving the American work force, need to be consolidated, to just 4 or 5 primary programs with training success being quantified and documented (Senator Mike DeWine in The Cincinnati Enquirer, 3 January 1997).

It is also known that the amount of training is a function of professional position } managers receive far more training than line workers (Carnevale, 1991), and professional associations } union labor receive significantly greater training than non-union labor (John Gray Institute, 1991), and direct-hires receive double the level of on-going training as contract labor (John Gray Institute, 1991). This directly contradicts conclusions drawn by several national agencies (Manufacturing Studies

Board, 1986; Office of Technology Assessment, 1988, 1990; US Department of Labor, 1993b). It is important to note that Japan, an economic giant, second only to the United States, spends consider- able time and effort on in-depth training of its line workers in a variety of skills (Muramatsu et al., 1987). Such philosophy is rarely seen in industry in the United States; exceptions are plants using Japanese management techniques (e.g., Honda of Ohio and Lucas-Sumitomo, Inc.).

Also of considerable importance is the fact that workers, in the present atmosphere of downsizing, need to be trained in a variety of skills to improve their chances of regaining meaningful employment. The need for such training has been reported by Muramatsu et al. (1987). Existing American industry training programs not only provide inadequate skill training for success in contemporary manufacturing, training programs are generally not linked to product designs (determining the manufacturing technologies and skills necessary to pro- duce a quality product). Without such linkage, it is not possible to optimize worker skills and, consequently, organizational productivity and product quality. Such a linkage would also assist in evaluating needs for updating and modernizing worker skills.

The paucity of on-site industrial training studies in the published literature is alarming, particularly since the economic well being of our nation de- pends on the skills of our workforce. The final National Science Foundation workshop report on workforce needs for global competitiveness, pre- pared by Mital (1996), stated that `... it is important to recognize the special role training has to play in preparing the American workforce for global com- petition beyond the year 2000a. This report also referred to President Clinton's 1996 State of the Union Address during which he stated that there are nearly 160 different Federal training programs and yet, according to Louis V. Gerstner, Jr. (CEO, IBM), we have a significant number of people in the workforce who can barely read, compute, communicate, or think (National Education Summit, Palisades, New York, April, 1996). Clearly, training related research, particularly industrial training re- search that is carried out in field is a dire necessity (Tannenbaum and Yukl, 1992) for the UnitedStates if we are to remain competitive in the global economy.

04. Conclusion

As pointed out in the previous sections, various national agencies (e.g. Office of Technology Assessment, US Department of Labor, National Academy of Engineering, and Manufacturing Studies Board), academic researchers (e.g. the National Science Foundation Workshop Reports), and industry leaders (e.g. Louis Gerstner, CEO, IBM) agree that workforce skill requirements have be- come greater and more complex as a result of investments in AMT. These investments are essential if the US industry is to remain competitive in the global economy. Further, it is necessary, and to industry advantage, for humans to remain an integral part of manufacturing environments for economic and cybernetic reasons.

The discussion in previous sections has revealed the scarcity of industrial training research, particularly, field studies. Given the complexities of modern manufacturing, the national need to be globally competitive, the need to retain and enhance the standard of living of Americans through gainful employment, and the increased burden placed on the skills required of the workforce (at all levels) line and maintenance workers, super- visors, professionals, and managers), it is absolutely essential that the United States initiate a comprehensive industrial training program. The dire necessity for such a program is further demonstrated by the fact that we have: workers who do not have skills industry needs (and such workers often remain without jobs for prolonged periods of time); a proliferation of training pro- grams that do not meet worker, industry, and national needs; inadequate training given to line workers; few transferrable skills possessed by workers; etc.

Realizing that the economic growth of our country is dependent upon developing our human re- sources (e.g. Coleman, 1988; Boothroyd, 1990; St. Charles, 1990) and the productivity of Americans is directly proportional to America's economy, it is essential that we develop an industry-based generictraining process that, at the very least:

- can enhance the skills of workers at all levels,
- allow them to dynamically cope with changing technology,
- give them options for personal and professional growth,

- cut costs, increase productivity, and quality of products manufactured, and
- make the U.S. human resource base second to none in the world.

07.References

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