Journal of
INDUSTRIAL TECHNOLOGY

Volume 16, Number 3 - May 2000 to July 2000

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By Dr. Radha Balamuralikrishna, Dr. Ragu Athinarayanan, & Dr. Xueshu Song

KEYWORD SEARCH

CAD
CAM
CIM
Curriculum
Higher Education
Management
Production

Reviewed Article

The Official Electronic Publication of the National Association of Industrial Technology • www.nait.org

Dr. Radha Balamuralikrishna (Bala) is a certified senior industrial technologist and assistant professor at Northern Illinois University. He earned the Bachelor' s degree in naval architecture and shipbuilding technology from Cochin University, India (1986), M.S.Engg. in ocean engineering from Florida Atlantic University (1990) and Ph.D. in industrial education and technology from Iowa State University (1997). Dr. Bala worked for Mazagon Docks Limited (a large shipyard in Bombay, India) for three years in the 1980s. He currently teaches primarily in the design area, but has also previously taught courses in quality control, statics, strength of materials, fluid power, and electricity.

Dr. Ragu Athinarayanan earned his B.S., M.S., and Ph.D degrees from Southern Illinois University at Carbondale, all in electrical engineering. He is currently assistant professor in Electrical Engineering Technology at Northern Illinois University (NIU). His area of specialization is digital systems and industrial controls. He has developed and delivered numerous courses in these areas for both industry and academia. Dr. Athinarayanan's research has been published in various professional journals and he has delivered presentations at both national and international conferences. He recently received the "Faculty of the Year" award from NIU's College of Engineering and Engineering Technology.

Dr. Xueshu Song is a licensed professional engineer in the State of Illinois, a principal investigator and project director of five National Science Foundation funded projects, an associate professor of technology and a part-time assistant director of Technology Commercialization Office at Northern Illinois University. Dr. Song has published widely in technology and engineering education as well as conducted research in mechanical and manufacturing engineering and has taught over a dozen courses in computer programming, welding, and fundamental engineering. He earned his Ph.D. from Penn State University.

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Introduction

Concurrent engineering has become a common phrase heard on factory floors and mentioned in the literature during the decade of the 1990s. The process of concurrent engineering has also been identified by business organizations as simultaneous engineering, life-cycle engineering, parallel engineering, multi-disciplinary team approach, or integrated product and process development (Hall, 1991; Ziemke & Spann, 1991 and Prasad, 1996). Concurrent engineering has become a key concept that has already enabled companies to attain world-class stature (Shina, 1991). There is a strong consensus that modern computer technology has been a major driving force behind the increased practice of concurrent engineering (Kelley, 1998). However, there is much more to this philosophy of managing the modern production organization than just advanced technology. The purpose of this paper is to provide a perspective of concurrent engineering from an industry point-of-view and translate these findings for industrial technology education.

Three T's of concurrent engineering: Industry point-of-view

Concurrent engineering preaches the simultaneous progress of activities required in getting new products out to the paying customer as quickly as possible. An examination of successful concurrent engineering transformations in industry revealed the presence of and interaction between three underlying elements (Society of Manufacturing Engineers, 1989). These elements, worthy of consideration as the three T's of concurrent engineering are:

- tools - involves the material infrastructure
- training - relates to the human aspect and includes educating personnel on the use of appropriate tools.
- time - considers realistic expectations in terms of setting targets

The three T's of concurrent engineering are dynamic by nature, that is, the type of tools, areas of training, and realistic estimates of time constantly change in light of new innovations and discoveries. Even though the three T's are also product-specific and company-specific, certain basic generalizations may be recognized.

Tools

The complexity and wide range of specialized disciplinary areas involved in modern manufacturing makes it an interdependent activity, often involving hundreds of personnel. In these circumstances, communication tools are of utmost importance (Kelley, 1998). The design function in manufacturing has universally embraced the idea that a picture is worth a thousand words. This paradigm although undergoing a major shift as explained later in this section, is still very prevalent in much of the world's manufacturing today.

For centuries, a blueprint from the design office has been the agent for production planning and subsequently, actual production. Today's concurrent engineering requires the paper blueprint of yesterday be replaced with an electronic three-dimensional solid model using any one of the computer aided design packages. State-of-the-art three-dimensional CAD systems typically employ feature-based and parametric modeling capabilities. These facilities in themselves have made the primary task of defining geometry faster and more flexible. Of course, the designer can use solid models simply to obtain feedback for improvement or to obtain approval from customers. The ability to create or manipulate a solid model on the computer is fast becoming a minimum pre-requisite to function in a technical capacity in the settings of a concurrent engineering environment. This is because CAD models lend themselves to several downstream applications (LaCourse, 1995). A case in point is rapid prototyping (Jacobs, 1996). This technology has caused industries to rethink from "a picture is worth a thousand words" to "a prototype is worth a thousand pictures."

The networking technology that enables transmission of complex 3-D geometry to virtually any part of the globe is by itself a significant tool. Release 18 of the Pro/Engineer CAD/CAM/CAE software (developed by Parametric Technologies Corporation, Waltham, Mass.) came with a Pro/WEB publish module that allowed users to extract data from Pro/Engineer design models for distribution through a World Wide Web (WWW) browser. This specific release was available for both UNIX and Windows operating systems (Deitz, 1997). Since then, Parametric Technologies have marketed newer releases of their design package. Further information is available at their web site http://www.ptc.com. Other CAD packages have included similar facilities in their recent versions (Leach, 1998). A noteworthy fact is the reduction in cycle time for new releases of design software. For example, Parametric Technologies Corporation updates its Pro/Engineer design modules once every six months. The creation of this sophisticated design package that combines the intellectual efforts of several individuals in parallel should in itself be an excellent example of concurrent engineering implementation. Aditham, Jain, and Srinivasan (1997) drew attention to two relatively recent technologies that have profoundly affected the way people communicate and share information, namely, the Internet and Java. Internet provides the network infrastructure and Java lends platform neutrality. These two technologies enable the construction of a common framework of collaboration that is free from the constraints of geographic separation and platform disparity.

Training

One of the greatest challenges in managing the simultaneous operation of inter-related tasks is to figure out ways that get people to work together as a team (Prasad, 1997). Human beings, by and large, have a natural tendency to be territorial and are likely to attach top priority to personal interests (Prasad, 1997). Typically, the business failures of production-based enterprises have been attributed to controversies between people within and/or external to the firm (Giritli & Ertan, 1997 and Cooper & Taleb-Bendiab, 1997). Employee adaptability to environmental changes is well known as a strategic tool for manufacturing competitiveness. Concurrent teams must be well versed on dealing with change constructively, regardless of how, where and when it occurs during the life cycle of a product.

At a minimum, the members of concurrent engineering teams need to recognize the following (Blankenburg & Wiik, 1997):

- it is not possible to create an optimal design by accident- it must happen collaboratively among people making the best use of resources.
- as team members, they should feel free to raise genuine questions and concerns
- the company's survival depends on customers willing to pay for the product rather than individual efficiencies or even overall productivity.

Personnel training in these basic areas is a key factor in realizing the bottom line goals of companies. Corporations have even established their own universities to provide company-specific training to their employees. As good as the pay back may be, initial investments in large-scale in-house training facilities are usually not feasible for small and medium size organizations.

Several companies have been innovative in their approach to the challenge for employee training. Specifically, the concept of establishing training consortiums maintained by a group of companies deserves attention. The mission of these consortiums is to create a competitive advantage for its members through "share-sourcing" of proven training expertise and innovative practices. Members pool their respective strengths by making their "personal best" training materials available for adoption and/or adaptation by other units in the group. The completed training modules are then put on an Intranet, which can only be accessed by members. An example would be *LearnShare*, a consortium created cooperatively through the companies Motorola, Owens-Illinois, Reynolds Metals, General Motors, Owens Corning, Iams, LOF (Pilkington), 3M, John Deere, and Steelcase (Corry, 1998). At least three universities, including Arizona State, The Ohio State, and Farleigh Dickinson currently participate in *LearnShare*.

Just as the need for more training is imminent, companies are also discovering that new technology continues to revolutionize the ways of education (Driscoll & Thomson, 1997). The growth of the Internet has created new avenues for training. Web-based technologies provide many benefits in delivering training and educational services, some of which, include (a) relatively low cost, (b) real-time, and (c) ease of access to sources of knowledge. Companies are more than willing to provide necessary infrastructure such as computers and Internet access so that their employees may receive training as needed and pursue the goal of never-ending continuous improvement, which in many cases has become an integral part of concurrent engineering efforts.

Time

As companies find that it is imperative to reduce the cycle time for new product development, they begin to think in terms of parallel activities. Although concurrent engineering is a relatively easy concept to understand, it takes much more for practical implementation. Reduced cycle time is just one of the many factors that affect the profit equation. The quality of the product and its cost to the customer are major determinants of success in the market. If a company is simply focused on reducing cycle time, the end result could yield poor quality products produced at premium costs in a shorter time period. This can be disastrous and depending on the extent of losses, the company may have to close its doors sooner than ever. It is safe to assume that a hurried implementation of concurrent engineering without careful planning and investment of time has a high probability of backfiring. It takes most companies approximately eight months just to become comfortable with a new CAD/CAM system (Marks & Riley, 1995).

The current trend in industry is to take the concept of concurrent engineering beyond the realms of the organization. This involves bringing the company's suppliers and customers within the boundaries of the organization. Sometimes, this innovative idea can create barriers in terms of time for implementation. Blankenburg & Wiik (1997) provided an interesting case study involving the Vingard Company, a world leader in producing electronic hotel door locks with magnetic card readers. In 1996, Vingard signed a contract with the hotel chain Motel 6 to deliver a specially designed lock for the 80,000 doors in the entire hotel chain. Design and development started in August 1996, and the first installations had to take place no later than the end of April 1997. Three-dimensional models were created on the computer and rapid prototyping was used to hasten the card key development process. Even though basic development of the product was completed in a record time of two months with cooperation among design, tooling and production, new hurdles appeared. Vingard's own production department and supplying contractors insisted on traditional 2-D drawings and documentation, as they were not prepared to work of 3-D computer data. The lesson here is that concurrent engineering also requires prior agreement between all affected parties on any advanced forms of design documentation. Clearly, considerable amounts of time must be devoted towards establishing such levels of understanding.

Implications for Industrial Technology Education

The discipline of industrial technology has its roots established in meeting the needs of business and industry (Shaw, 1991). The replacement of "over-the-wall engineering" with concurrent engineering has thrown open an exciting new world of opportunities for industrial technology graduates. In a simultaneous engineering environment, industrial technologists can expect to have the opportunity to be actively involved in the product as it evolves from the cradle up to the point of its obsolescence into the grave. This is in sharp contrast to the former paradigm of over-the-wall engineering where industrial technologists received communication from the designers and were simply asked to produce according to specifications with little or no opportunity to provide any feedback. Industry expectations of industrial technology graduates will continue to change significantly in light of the popularity of concurrent engineering concepts. It is the responsibility of all industrial technology educators to consider these changes and prepare students to meet future workplace challenges with confidence.

Mason (1998) conducted a survey of managers/engineers representing one hundred Pacific Northwest companies to assess their perceptions on manufacturing practices and curriculum recommendations for a new manufacturing engineering program. The participants in this study predicted that CAD, computer networks, and concurrent engineering would each become twice as important (compared to the present) in industry within the next five years. Futuristic predictions along the same lines have appeared specifically in industrial technology literature (Kelley, 1998). However, the impact of concurrent engineering and associated industry needs have yet to be translated into a new curriculum model for industrial technology.

The development of an industrial technology curriculum model that captures the concurrent engineering intent of industry is by no means a simple task. In close comparison to industry, colleges and universities also require the three Ts (tools, training, and time) for designing a curriculum that would prepare students for the challenges of a concurrent engineering environment. By design, a typical industrial technology program includes courses from the three broad areas of general education, technology, and management. Within this framework and philosophy, there is ample room to provide students with many of the competencies required to operate in a concurrent engineering environment.

Recognizing that industrial activities tend to be more multi-disciplinary and inter-active, future curriculum designs should emphasize collaboration of industrial technology students with their peers from other departments across the institution. Misconceptions, ill-based perceptions, and artificial barriers have caused even closely similar academic groups such as engineering, engineering technology, and industrial technology to remain isolated in the academic environment (Kasuba, 1996). The faculty and administrators from various academic departments, in particular, those from industrial technology need to explore avenues to pattern their institutional operations after the concurrent engineering movement in industry. Concurrent engineering will continue to present both opportunities and challenges for industrial technology educators and practitioners during the new millenium.

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