Enhancing Instruction in Lean Manufacturing through Development of Simulation Activities in Shipbuilding Operations

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Abstract

Lean Manufacturing is a powerful philosophy that advocates minimization of waste within an organization. The adoption of Lean Manufacturing philosophy by major manufacturers has created a demand for qualified personnel in this area. A training program in Lean Enterprise was developed by Old Dominion University for the Apprentice School at Northrop Grumman Newport News. Physical simulation activities are an integral part of this training program. Simulation activities related to shipbuilding operations have been incorporated in the Lean training course. These activities have been used in the Business Operations course for three semesters. Results show increased student participation and better understanding of lean concepts.

The paper discusses the structure of the simulation activities and their effect on learning of Lean concepts. The paper also discusses measurement of performance metrics to evaluate the impact of lean concepts. An attitudinal survey has been developed to assess the impact of the training program on student's thinking.

I. Introduction

The adoption of Lean Manufacturing philosophy by manufacturer's worldwide has created a demand for workers who are trained in the lean principles and have an eye for the waste in the value stream [1]. The Lean Enterprise training program is designed to train students who are technically qualified in the implementation techniques of lean.

The training program has been developed under the summer faculty internship program offered by Northrop Grumman Newport News. A faculty member in the Engineering Technology Department at Old Dominion University (ODU) developed the training program and associated simulation activities while participating in a summer faculty internship program.

The training program is modular in nature and contains seven modules, which can be either used independently or as one cohesive unit. Upon completion of this course, the students will understand the fundamental principles of lean and the value of reducing waste within an organization. They will be familiar with various techniques for implementing lean on the shop floor including value stream mapping, 5S, cellular manufacturing, interdisciplinary teams, perfect quality and pull scheduling.

A number of organizations have failed in the implementation of lean manufacturing by failing to sustain it [2, 3, 8]. The energy to sustain often comes from employees who understand the lean principles and have made them part of their daily routine. This training program will help sustain the implementation process by producing apprentice graduates who are versed in the lean principles.

II. What is LEAN ?

The term lean was first coined about 15 years ago at Massachusetts Institute of Technology and later published in a book called *Machine That Changed the World,* written by James Womack and his colleagues [4]. The generally accepted definition of lean in the industrial community is that it is:

"A systematic approach to identifying and eliminating waste (non-value-added activities) through continuous improvement by flowing the product at the pull of the customer in pursuit of perfection."

The lean principles have evolved from the works of Henry Ford and subsequent development of Toyota Production System in Japan. Lean manufacturing principles improve productivity by eliminating waste from the product's value stream and by making the product flow through the value stream without interruptions [1, 4, 5]. This system in essence shifts the focus from individual machines and their utilization to the flow of the product through processes [7].

In their book *Lean Thinking*, James Womack and Dan Jones [1] outline five steps for implementing lean:

1. Specify the *value* desired by the customer.
2. Identify the *value stream* for each product and challenge all waste.
3. Make the product *flow* through the value creating steps.
4. Introduce *pull* between all steps where continuous flow is possible.
5. Manage toward *perfection* by continuously improving the process.

When lean principles are applied not just to manufacturing but to business operations not only within the organization and across all supply chains, a lean enterprise is created. The training program contains a module on lean enterprise which discuses the issues involved in the transition of a company to lean enterprise.

III. Apprentice School at Northrop Grumman Newport News

Throughout recorded history, apprentice training has served as a vital means of preserving and continuing craftsmanship. In the ancient civilizations of Greece and Egypt, apprenticeships reached a high state of development.

An apprenticeship is a formal training program, which allows a person to receive thorough instruction and experience - both theoretical and practical - in the various aspects of a skilled trade. Today's apprentices are fully trained, well-paid men and women acquiring skills and knowledge that will serve them well throughout their careers.

The Apprentice School of Northrop Grumman Newport News offers four-year, tuition-free apprenticeships in 17 skilled trades to qualified men and women. Apprentices work a regular 40-hour week and are paid for all work, including time spent in academic classes. Two optional design and production planning apprenticeship programs are available for selected apprentices after completion of required academics and about two years in craft training. The five-year design program prepares individuals in one of six design disciplines, including hull, machinery design, electrical, piping, ventilation and nuclear design. The four and a half year program prepares individuals for planning positions at various levels within the organization.

IV. Physical Simulation as a Teaching Tool

Physical simulations have a proven record as a teaching tool. Concepts often hard to grasp are made easy by the use of simulation exercises. During the simulation exercises, students take on role-playing within a manufacturing organization. Effect of various Lean tools on the productivity of the organization is studied and documented through measurement of performance metrics. These performance metrics include, work in progress, cycle time, profit/loss, production volume etc. During the current training program, simulation is performed in three phases each thirty minutes long. Module-7 of the training program includes two simulation exercises.

V. Incorporating Lean Training in the Core and Advanced Design Curriculum

The training program has been tested in The Apprentice School classes at both the core and advanced program levels. Student responses have been collected and evaluated. Student and Instructor comments have been utilized to modify the presentations. Student comments indicated positive response towards the program content and method of presentation. The comments showed a positive attitude toward lean and the possibility of implementing lean in various areas throughout the company.

The training program has recently been incorporated into one of the schools business classes (B112 – Problem Solving & Decision Making in Industrial Environments). The goal of this course is to provide the student with competency-based, hands-on learning that supports a systems approach to team problem solving and decision making while improving a process. A prerequisite course introduces students to the concepts of teams, team building and development, and basic human behavior. Having this knowledge, each student is expected to participate and sometimes lead a team in studying and improving a real process (implementing lean concepts) within the company.

VI. Attitudinal Survey to Assess Impact of Lean Training

The challenge of Lean training programs is in changing how people feel about manufacturing. Application of tools is relatively simple compared to the changing the work culture and attitudes. Thus, it is important to assess the change in the attitude of people.

Assessment is an integral part of this training program. An attitudinal survey was created to assess the impact of lean training on the thinking of students. The attitudinal survey assesses how students' thinking about lean manufacturing has changed during the training. A score is generated from the survey from pre and post testing. The difference in the score represents the change in the attitude of students. Thus, a larger difference represents higher impact of training program on student's thinking.

V. Structure of the Training Program

The lean training program is divided into 7 individual modules of instruction as shown in Figure-1. The first six modules provide the theoretical knowledge about lean manufacturing, and the last module incorporates the knowledge base of the first six modules in the form of simulation exercises. The first module is designed to provide a brief history of the evolution of manufacturing techniques and the founding principles of lean. It provides the big picture of the lean concepts.

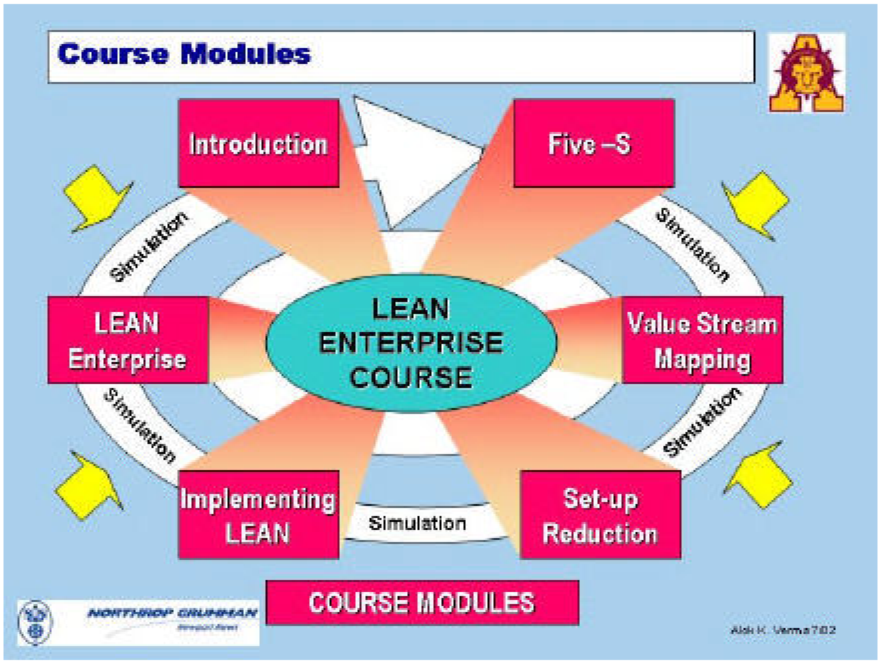

Figure-1. Course Structure

Modules 2, 3, and 4, deal with specific techniques for implementing lean. These modules can be taught out of sequence. Module 5 deals with the implementation process and module 6 deals with the concept of lean enterprise and the transition from lean manufacturing to lean enterprise.

VI. Delivery Method

The course is instructor-led classroom training combined with in-class simulation exercises designed to invite class participation. This approach aids in the individualized instruction given to the participant. Instructional methods include facilitated discussion, hands-on simulation of production, and on-the-job practical applications. PowerPoint presentations are used to deliver the course supplemented by a series of videotapes from Society of Manufacturing Engineers and Productivity Inc. Students are encouraged to participate in the lean implementation projects.

VII. Compartment Simulation Exercises

This exercise simulates the fabrication and outfitting of an aircraft carrier compartment as shown in Figure –2 and 3. An aircraft carrier may have typically several hundred of these compartments for use by officers. This work area was chosen as a representative fabrication task since it incorporates all scheduling and logistical problems. During the simulation, students track performance metrics like lead-time, cycle time and throughput while implementing various tools of lean in three phases. This exercise takes into account logistical issues such as inspection reports, engineering reports, getting a drawing from a drawing vault, and employee absenteeism, in addition to fabrication and outfitting. It also involves issues related to supply chain such as delivery lead-time for furniture and other components.

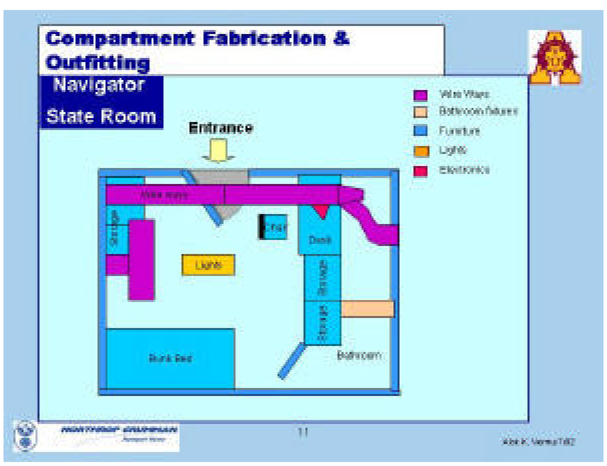

Figure-2. Compartment Layout

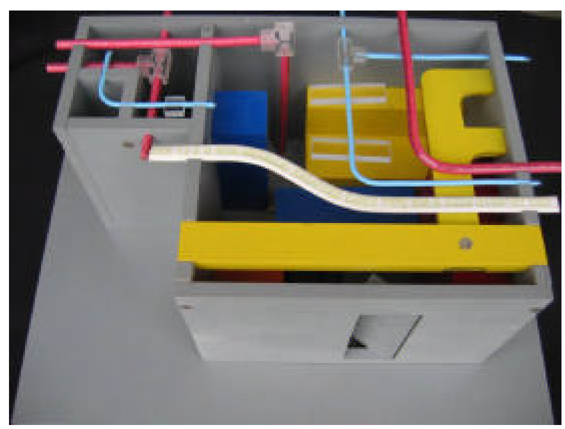

Figure-3. Compartment Model

The simulation exercise starts with the traditional manufacturing model involving push system and functional layout. During the second phase, lean concepts like 5-S, standardized work and empowered teams are incorporated. Finally, during the third phase concepts like cellular manufacturing, pull system and point-of-use-storage are implemented. These three phases of simulation activity are shown in Figure 3.

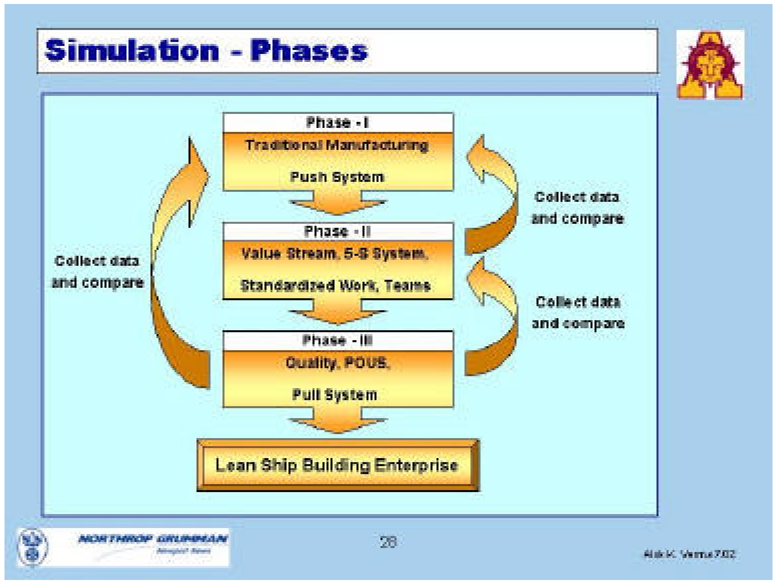

Figure-3. Simulation Phases

VIII. The Physical Model

The physical model of the compartment is a scaled model of a navigator's stateroom aboard a Nimitz-class aircraft carrier. The pattern shop at NGNN made the models. The components are fabricated from wood and include furniture, walls, piping, wire ways, lights and bathroom fixtures. The components are assembled together using dowel pins for positioning and fastened with brass screws. The sequence of assembly resembles the actual fabrication of the compartment except for the wire ways and heating and ventilation ducts. These components are assembled last to facilitate assembly inside the compartment. Thirty pieces were made of each component. The components are designed to withstand repeated assembly and disassembly.

IX. Implementation of the Training Program at Apprentice School

The Lean Enterprise Course can be either implemented as a stand-alone course or in the form of individual modules in various Apprentice School courses. It is recommended that all the modules be viewed in the numeric sequence when used as a complete course. The last module is designed to bring together the knowledge gained in the first six modules and challenge students to apply it to simulation exercises, further enhancing the understanding of lean concepts.

X. Implementation of the Simulation Exercise

As discussed in section V above, the lean modules were implemented in a course titled Problem Solving & Decision Making in Industrial Environments. After being introduced to theoretical knowledge about lean manufacturing, the students are asked to simulate the process of fabricating and outfitting an aircraft carrier compartment. The student, being apprentices in various trades while not in class, are quite familiar with this room and all that is involved. The simulation begins with the class establishing themselves as a company with the fictitious name being Shipbuilding Enterprise (SBE). The cost variables such as sales price, materials, facilities, and labor are discussed and determined between the teacher and the students. This allows for much buy-in from the students' standpoint. Job responsibilities are discussed and a very short interview process is held where students volunteer for the many positions needed to manufacture the product. The goal for the company is to turn a profit, with a larger profit being the better. As The Apprentice School usually conducts four Problem Solving sections per semester, the classes typically compete against each other on which can gain the largest profit. This competition among classes usually sparks great enthusiasm in all involved.

Once the SBE business is thoroughly established, the company makes its first attempt at building compartments. The traditional manufacturing method is used to make as many compartments as possible. The company employees are given strict rules to follow that are standard in traditional manufacturing arenas. Data is collected after working an entire shift. Average cycle time, WIP, units on time, late units, total units, number of employees and workstations, distance traveled, and number of units passed/failed are the performance metrics that are analyzed. The numbers are input into an Excel spreadsheet and the bottom line profit is examined. In most cases round one turns a negative profit, and in most cases the company does not get a single compartment built.

It is at this point that the students are reminded of some of the lean concept taught earlier in the class. Although the company does not employ a "pull" system during phase II, they do begin to use several of the lean building blocks to improve the process. Ideas such as point of use storage, 5S, multi-functional workers, and standardization surface quickly in group discussion. Systematically, the students begin to implement lean ideas, and thus improving the process and turning greater profits. The second phase is completed and data collected. This run usually produces a break-even bottom line. The students are usually excited to see the turnaround that they are responsible for; however they are reminded that the company cannot survive by simply having each shift break even.

As the students return to the table to brainstorm ideas of how they might improve the process even greater, a more thorough lecture is given on the "pull" system of manufacturing. The students then set-up and run the process a third time implementing as many of the lean concepts as possible, including the pull system. The data after one shift is collected and the bottom line is computed. Typically, the profit gain exceeds the initial loss made during phase I. At this point the students are quite excited and are very proud of their accomplishments.

XI. Results

The lean modules have been well received by The Apprentice School and its students. Comments at the end of course surveys reveal that student enjoy learning the lean concepts with the simulation exercise. Many supervisors on the job have reported that the students, after having the class, are more involved with improving processes and making them leaner. The attitudinal survey will be administered during the semester to assess impact of lean training and results from this survey will be presented during the conference.

XII. Conclusions

The lean training program developed for The Apprentice School at Northrop Grumman provides flexibility in implementing the training program. Each of the modules can be either used on their own or used together in a comprehensive training program. The program is designed to train students in the principles of lean manufacturing and how an organization can be transformed into a lean enterprise. Student learning is enhanced by examples of actual lean implementations in various industries both in USA and abroad. Hands-on simulation exercises provide understanding of the concepts and first hand verification of the advantages of lean.

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Biography

ALOK K. VERMA

Alok K. Verma is Associate Professor and, Director of the Automated Manufacturing Laboratory at Old Dominion University. He received his B.S. in Aeronautical Engineering in 1978 and MS in Engineering Mechanics in 1981. Alok is a licensed professional engineer in the state of Virginia, a certified manufacturing engineer and has certification in Lean Manufacturing and Six Sigma. His publications are in the areas of Lean Manufacturing, Process Automation and improvement, Advanced Manufacturing Processes, CAD/CAM, and Robotics. His current research interests are in the area of process optimization and Lean implementation models for job shop and designed to build environments. Alok Verma has co-edited the proceedings of the International Conference on CAD/CAM & Robotics for which he was the general chairman. He is serving as the associate editor for the International Journal of Agile Manufacturing. Alok has developed the training program in Lean Enterprise for Northrop Grumman Newport News Apprentice School and continues his participation through a joint National Shipbuilding Research Program (NSRP) project to develop and design new simulation tools for Lean enterprise training. He is active in ASME, ASEE and SME.

JAMES HUGHES

Jim is Manager, Training with the Apprentice School of Northrop Grumman Newport News. He is responsible for academics and administration for the 650-student program. The Apprentice School provides education and training in skilled trades, design disciplines, and production planning. Apprentices complete a four- or five-year program of study and work experience. Prior to joining The Apprentice School in 1985, Jim was an Assistant Professor, School of Education and Psychology, at North Carolina State University. Jim also served as curriculum consultant to the Saudi Technical Development Project for Saudi Aramco and was special projects director for the National Association for Industry-Education Cooperation. Jim earned an undergraduate degree from Middle Tennessee State University, a master's degree from the University of Tennessee at Knoxville, and a doctorate from the University of North Carolina at Chapel Hill.

SCOTT CHRISTMAN

Scott Christman is a native of Poquoson, Virginia. He attended Newport News Shipbuilding Apprentice School, from which he graduated as a pipefitter in 1986. Scott continued his education at Old Dominion University and completed his BS degree in engineering technology in 1992. Scott became interested in education and training and sought additional education. He completed his second BS degree and his MS degree in occupational and technical studies in 1994. Scott attended West Virginia University from 1994-1997 and completed doctoral program courses in technology education. Scott returned to Newport News Shipbuilding in 1996 as an apprentice academic instructor for The Apprentice School. He teaches mathematics, physical science, computer, and business courses.

THE APPRENTICE SCHOOL

The Apprentice School is an operating department of Northrop Grumman Newport News, Newport News, Virginia. The School enrolls approximately 715 apprentices in 19 different trades that support the work of the company, construction, overhaul, and repair of nuclear-powered aircraft carriers and submarines, and fleet maintenance support.