

## **AC 2008-1400: APPLICATION OF LEAN CONCEPTS TO THE TEACHING OF LEAN SYSTEMS**

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# Application of Lean Concepts to the Teaching of Lean Manufacturing

## 1. Introduction

Lean manufacturing organizations, such as Toyota Motor Corporation (TMC), are often described through their outward attributes: just-in-time inventory control, kaizen, emphasis on quality-at-the-source, empowered workers and teams, standardized work, etc. We maintain that these visible characteristics of Lean organizations are intended to support the organization as a continuous learning organization. The systems associated with lean are implemented to enhance the learning of the individuals and the organization itself in a drive for continuous improvement. When successfully implemented, these systems establish a problem-solving culture within the organization, where teams and groups continuously learn, adapt, and improve on a daily basis.

In teaching Lean manufacturing in a university setting, educators must teach the content (tools, techniques, and structures) of Lean. Educators should also teach about the culture of lean. If we believe that the structures of lean are effective in enhancing learning in the industry setting and in building a problem-solving culture, then we should consider how these same structures can be translated into the classroom setting. The goal is not only to improve learning, but also to “practice what we preach”. The teaching of a continuous improving lean system curriculum, at its core, is contingent on developing and deploying a well institutionalized, continuous improving, problem solving culture within the classroom. This paper will argue that TMC’s continuous learning lean system is applicable in teaching a lean curriculum at the university college of engineering level.

In the next section, we describe the way in which a lean manufacturing organization is a continuous learning system. This is presented in the context of the “universal continuous learning model” of Fujio Cho during his 1986-1995 startup activities at TMC’s Georgetown, Kentucky facility. In subsequent sections, we consider the four elements of continuous learning systems. For each element, we overview what that element means within an industrial setting, and how those ideas are translated into a classroom setting to support a curriculum for undergraduate and graduate education in Lean manufacturing at the University of Kentucky. Section 6 outlines a Lean manufacturing curriculum as it is implemented at one university. Section 7 concludes with some summary statements.

## 2. Continuous Learning Systems Theory

Dr. Walter A. Shewhart was the first to define “continuous learning” in a production system when he argued that the three steps in a production process: *specification*, *production*, and *inspection*, must go in a circle rather than a straight line to achieve continuous improving product quality. He further argued, these three steps are better conceptualized as the three steps in the scientific method; that is, *specification*, *production* and *inspection* correspond respectively to “*making a hypothesis, carrying out an experiment, and testing the hypothesis*”<sup>1</sup>. Shewhart

further argued that these three steps constitute a “*dynamic scientific process for acquiring knowledge*”<sup>2</sup>.

Dr. W. Edwards Deming, a colleague of Dr. Shewhart, made a significant addition to Shewhart’s three step learning cycle by adding a vital fourth step, his “Act” step. Deming argued that his fourth step in a given cycle of improvement should lead to a new operating standard<sup>3</sup>. The Shewhart and Deming well-known learning cycles, Plan-Do-Check (PDC) and Plan-Do-Check-Act (PDCA), respectively<sup>4</sup>, were developed and utilized as means to continuously improve the quality of military hardware during World War II. Dr. W. Edwards Deming introduced the Shewhart concept of continuous learning to Japanese leaders on June 16, 1950.

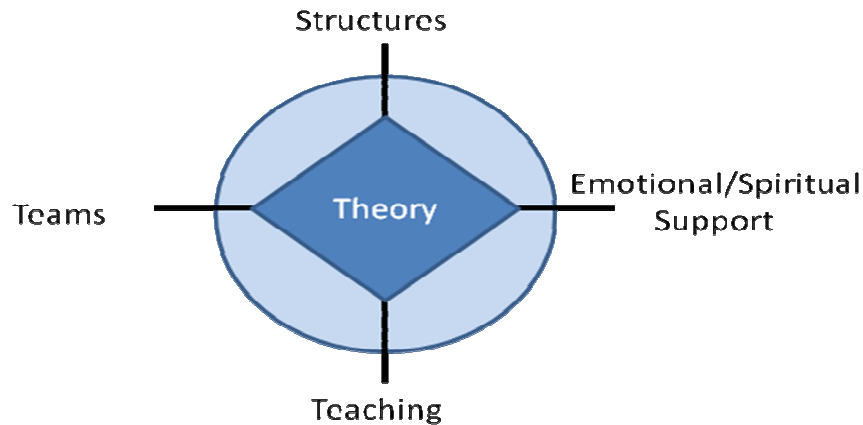
Toyota’s leaders first began to apply the Deming “learning cycle” as their basis for designing a continuous learning system in the early 1950s<sup>4</sup>. Their continuous learning philosophy is now well articulated as: “Find the problem, fix the problem, and keep the problem from coming back.” Their organization learning strategy is known around the world by the Japanese word *kaizen*; *kaizen* (continuous improvement) activities are practiced at every Toyota facility as an ongoing, never ending way of doing business. *Kaizen*, in a Toyota sense, means small step-by-step, incremental improvements as the normal part of doing work. Their concept of small, incremental steps of learning more accurately matches the way all humans learn, which is reflected in sequences of small incremental steps of discovery.

The essence of the TMC *kaizen* philosophy moved industrial engineering to the shop floor and delegated its execution to teams and groups of team members; all team members, in this sense, are expected to perform industrial engineering activities with a “*kaizen eye*.” Many of the tools and structures that were developed or adopted by TMC (and other lean organizations) were to support this continuous improvement culture, by making problems evident, providing problem-solving skills and empowerment to fix the problems, and by providing the organizational knowledge structures (such as standardized work) in order to keep the problems from reoccurring.

The continuous learning system theory has four arms to it<sup>3</sup>, as illustrated in figure 1:

1. Technical, Organizational, and Leadership Structures that support inquiry learning,
2. Collaborative Teams that require communication and reinforce the continuous learning system culture,
3. Instructional strategies that develop and capture knowledge within the organization,
4. The emotional and spiritual support of the team members

In the following sections, we examine these four elements, and consider specifically how the concepts are brought to the classroom setting.



### **3. Structures That Support Inquiry Learning**

Experienced teachers know that the first step to effective learning begins with the creation of a learning environment. Among the first acts of Dr. Fujio Cho, chief operating executive of TMC's Georgetown, Kentucky start-up operations, was to direct the design of a system that supported continuous improvement before attempting to train his team members in kaizen, visual management, setup reduction and various other tools of his lean system. Cho's learning structure has now been in existence for more than twenty years at Georgetown, Kentucky and it continues to improve from year to year; it is a never ending quest.

There are three categories of structures in the design of inquiry learning, continuous improving organizations. They are: technical structures, organizational structure, and leadership structures.

The technical structures within Lean include the production control methods, the standardized work methods, the plant layouts, and others. The physical layout of a lean system and that of an inquiry learning classroom have a common thread; they are both designed to facilitate learning. Peter Senge, in his book, *The Fifth Discipline*, has suggested concerning structure, that team members within these structures have tendencies to produce quantitatively similar results<sup>5</sup>. Layout can include bright lighting to facilitate quality production, minimizing extraneous or distracting items (a benefit of Lean's 5S), and equipment and materials arrangements that make out-of-standard situations evident. (In the classroom, this could equate to having standardized locations for instructional equipment and materials, so that missing items or malfunctioning equipment are evident).

A common structure in lean is the cellular layout. The cellular layout places dissimilar machines within small cellular patterns, or small circular arrangements that permit a few operators to guide production on each machine, providing for multi-skilled team member development. The team member in this arrangement has opportunities to learn and become a more valuable team member to the organization.<sup>6</sup> Compare this cell of production, perhaps with a small team of three workers, to that of a team of three students working within a classroom setting on a common problem. A team of four to six students working on common problems provides

opportunities for more learning<sup>7</sup>; the grouping of students facilitates communication, creating opportunities for the students to learn from each other.<sup>8</sup>

In contrast to Lean, conventional manufacturing layout patterns are designed to focus on specialization in functional layouts. This is reflected, for example, by placing all the grinder machines grouped together in a common department, all the broach machines grouped together in a common department, and so forth. Team member operators who do the work at these various machines are specialized; their work activities are dedicated to only one type of machine eight hours each day and for weeks and months into the future. There is much less opportunity for collaborative learning with such a layout, just as a traditional lecture hall design discourages communication, collaboration, and participation.

In the classroom setting, we have even modified the classroom scheduling to support cross-functionality. Traditionally, each course is taught by a single instructor, almost in isolation from other courses. This is equivalent to a functional factory layout. In our summer programs, we teach courses in pairs (two courses at three credit hours each). These courses are highly integrated. For example, a factory simulation exercise may be demonstrating technical structures (like production control or quality methods) for one of the classes, while simultaneously being a demonstration of team-skills or organizational behaviors for the second course.

The organizational structures within Lean are established to support inquiry learning also. These structures include low employee to supervisor ratios, flat organizational structures with empowered employees, an organizational focus on the value stream, and matrix organizational structures that force communication between different groups. In the academic world, some of these same principles can be applied. Student/faculty ratios in the classroom can be kept small, teaching support staff can be empowered to assist the students (the value stream), and regular communication forums can be developed.

The leadership of an organization is another structure that has the ability to support or undermine the inquiry learning environment. What is necessary is a leadership that recognizes and understands the importance of learning, and supports this. Fujio Cho, when discussing the implementation of the Toyota Production System (TPS) at the Georgetown Kentucky plant, stated the following:

*One of the first steps for TPS implementation at our Kentucky facility was a candid discussion between our Japanese and American managers. Together we were able to craft the basic philosophy....From the very earliest days of Toyota Motor Manufacturing, or TMM as we'll call it, we have been committed to learning from each other. We have taken these lessons and modeled a production and management system that blends the strengths of both cultures [Japanese & American] for our operations.<sup>9</sup>*

Note that “learning” is recognized by Cho as very key to the management philosophy. An environment that encourages controlled experimentation and advancement of knowledge is critical for a continuous improvement environment, and is contrasted to an environment of fear

or rigidity. In the classroom, this means that students should be able to ask questions, and the instructors should be open to explore new ideas with the students.

#### 4. **Deploy a Collaborative Problem Solving Environment**

Organizations are contrived social systems designed to accomplish, through group means, some specific purpose.<sup>10</sup> John Kenneth Galbraith has identified the basic components of an organization.<sup>11</sup> First, organizations are composed of groups and teams. Toyota has made groups and teams their basic structure at the shop floor level. Second, in almost all cases, these groups and teams, in order to accomplish organization objectives, utilize the differentiation mechanism in divisions of labor, and specialization of skills. Toyota employs the concept of standardized work as their means of differentiation mechanism; however, their focus is more on developing multi-skilled workers, meaning that team members are developed to be flexible and adaptable to many different work assignments. Toyota uses the Dr. Deming argument that on-the-job training is fundamental to skill development. Toyota uses this training strategy at all levels.

It was already discussed above that certain structures of the system, such as facility layout, encourage or discourage collaboration. In this section, we will discuss more specifically the importance of the collaboration in Lean, and the extension of those ideas for use in the classroom.

Collaborative teams are a fundamental element of a lean manufacturing system. The team structure is used for several reasons in a lean company. The first reason for teams is the recognition that the value of the teams can exceed the sum of the individuals. Tasks that are beyond the scope of an individual can be accomplished through teamwork. For example, different people bring different knowledge, viewpoints, and skills. The collection of these within a team allows a team to engage in better problem solving than a single person could. In a similar manner, in the classroom setting, the use of teams helps students to develop better solutions than individuals. The collective contributions among team members also lead to a second important reason for teams: the sharing of ideas within a team leads to cross-learning among the team members.

A third reason for teams within a Lean organization is to help in buy-in for decisions. Team members that have engaged in the decision making process will have better understanding of the reasons for that decision, and thus a stake in supporting that decision. They also represent a resource to communicate the reasoning to others in the organization. Others beyond the team may also have more confidence in the team decisions because of the belief that the team collectively evaluated the different alternatives.

A fourth reason for teams within a Lean organization is for establishing culture. The building of a continuous improving culture mandates that the focus be placed on teams and groups and not necessarily on individuals. At TMC, decisions are made by at least two team members, as is the Japanese cultural norm<sup>12</sup> – The establishment of team structures encourages the collaborative decision making that TMC values. In this case, the small team dynamics and peer influences within a team have the effect of pulling together organizational behaviors of its members. A

quality circle team, for example, may be less about solving a specific problem, and instead be about involving a group of people in a problem solving process.

Many of the same reasons that a Lean organization uses teams are also reasons for teams to be used in a course: Teams are able to accomplish more than individuals, there is learning between members on a team, and teams are a way of developing and disseminating a culture. In the classroom, the culture that should be developed among the students through the use of teams *is* a culture of collaboration and problem-solving. No amount of lecturing on the value of teams or the value of collaborative problem solving can replace the learning or experiencing of actually being a part of a team. It should be noted that teams can be formal or informal; for a large semester project, teams may work together for weeks, but informal teams may develop during small class discussions or class exercises.

A potential hazard of using teams within a classroom is that the teams may be ineffective, thus reinforcing bad practices among members rather than developing good team skills. In many lean organizations, training is used to establish a foundation of good team behaviors. At Toyota, new employee training begins with what is called *New Team Member Basic Training*. This is a one week highly structured program that introduces the new team member into a team setting.

Although many companies recognize the need to provide training in collaborative team behaviors, this is not typical in universities. ABET, the accreditation body for engineering programs, even requires that students graduating from an accredited program must have “an ability to function on multidisciplinary teams”. However, although team activities have become common in engineering curricula, actual instruction or coaching on good team behaviors is less common – university instructors often assume that students understand effective collaborative team behaviors through the students’ past experiences or through other classes. It is our experience, however, that this is often not true. Consequently, we include team training early within our curriculum, within our Lean Operations Management course. Students learn this material so that they can personally be more effective in teams, as well as guide others (whether in the university or in the workplace) to be more effective in teams. This common foundation of the students helps the students have a common framework of expectations regarding team behaviors later in the curriculum.

##### **5. Instructional strategies that develop and capture knowledge within the organization,**

The lean system of learning and change is equivalent to that known in the academic discipline as “discovery learning.” The name “inquiry learning” is perhaps a better description because, at every increment and element of production, the team member is encouraged to inquire into the validity of what is being done or has been done with a kaizen eye focused on improvement.<sup>3</sup> The lean structure, as briefly outlined above, is organized to facilitate learning.

We argue the fundamental operating structures of lean systems are driven by a holistic integration of well-know instructional strategies and principles. Toyota leaders have argued in their *Job Instruction Training Handbook* that every leader must constantly improve his or her teaching skills.<sup>13</sup> Given this hypothesis, we define two kinds of teaching strategies: the

*expository mode* and the *hypothesis (hypothetical) mode*. The expository mode, perhaps better known in engineering colleges as the lecture mode, puts all the content, pace, media, and style bounded in the professor; his or her students are “seat-bound” listener with rare opportunities to contribute to the learning environment. This mode is precisely modeled in industry by typical mass production supervisors; his or her team members are expected to listen and follow instructions.

Various studies have been conducted to determine the learner-teacher interaction behavior patterns in a typical classroom setting. The overall findings from these studies have concluded that teachers have a strong tendency to lecture.<sup>14</sup> Others have found the pattern of instruction to follow lecture, directed questions, demonstrations, and discussion.<sup>15</sup> The overall tendency is for teachers to present more material than a student can absorb in a given lecture period.

The *hypothesis* (Bruner calls this *hypothetical*) mode places the student in an active learning role.<sup>16</sup> The supervisor and the team member, in a lean setting, are collaborative partners in formulating and experimenting with alternative opportunities for improvement. As discussed previously, the four step PDCA is bounded in collaborative team member and team activities; it is a “dynamic scientific process for acquiring knowledge” through first stating a hypothesis (Plan), then carrying out an experiment (Do), followed by an analysis of results (Check), and finally, establishing a new standard (Act). All lean systems are structured to facilitate the hypothesis mode.

What are the benefits derived to team members when a hypothesis mode of instruction is deployed within a lean system? Dr. Jerome Bruner, a leading proponent of the hypothesis mode of instruction, has identified four benefits that may be derived from the experiences of learning through discovery.<sup>16</sup> His four benefits are: increased cognitive skill, intrinsic rewards for the individual, learning the heuristics of discovery, and an aid in conserving memory. Adopting hypothesis mode of instruction in the classroom will also bring these benefits to the students. One way of bringing this mode of instruction is to provide a variety of simulated factory experiences (such as discussed below) that allow a student to follow the PDCA cycle: developing a hypothesis (such as a proposed improvement to the system), carrying out an experiment (to see the effect of their changes), and then analyzing the results.

The Japanese expression “genchi genbutsu” means “go and see for yourself”. The expression is often used by lean manufacturing organizations to state that knowledge is best gained by direct observation. In Lean, this means that people should directly observe the manufacturing system. No amount of data or second-hand reporting can replace the experience of direct observation. Kiichiro Toyoda, the founder of TMC, emphasized the need to learn through the hands-on experiences of team members. This was his guiding principle, as it reflected Japanese cultural beliefs to reflect on and ponder the meaning of immediate experiences.<sup>12</sup> David Kolb has developed a well-known cognitive learning styles model that has as its first step the value of experience followed by reflection.<sup>17</sup>



Within the classroom, we can apply the principle of Genchi Genbutsu through simulated factory experiences and through visits to manufacturing facilities. Written industry case studies from past faculty or student projects are also effective, although not as desirable.

- Simulated experiences: Throughout the curriculum, we expose student to a series of simulated factory experiences. These range from simple “factories” assembling LEGO products, to more sophisticated simulations that manufacture functional pneumatic products, electronic products, and furniture products. Each of these simulations is designed with sufficient complexity to allow significant demonstration of different lean principles, but with enough simplicity to allow rapid collection of data and allow rapid modifications by students to implement improvements. It should be emphasized that these simulations are not set up to be demonstrations of good lean systems! Instead, they are set up with many opportunities for students to improve them. Students become involved in redesign of layout, production control, changeovers, quality systems, management systems, and most other aspects of lean. The learning experience of finding and implementing improvements is more important than seeing a simple demonstration.
- Company visits and projects: Our program also exposes students to real manufacturing systems, not just simulated ones. Our program has established good relationships with a number of regional companies. These companies welcome student teams for tours and also to study their operations and make recommendations for improvements. Through these experiences, students begin to understand the complexities of implementing lean. They understand that the people issues, the culture, and the leadership of the operation are often even more important than the technical issues of improving a system. The student teams develop proposed solutions that are presented to the company management. The companies appreciate the fresh insights and recommendations from the students. Companies also benefit from the self-reflection that they experience from explaining and discussing their operations with the students.
- Industry case studies: Although not as effective as simulated experiences or company projects, industry case studies can still be very helpful in letting the students analyze real systems and understand real-world constraints and complexities. The program faculty members have significant experience interacting with companies directly, and the program has a history of past industry projects tackled by student teams or for student masters projects. Sometimes industry projects where the students visit companies and collect data may not be feasible, either due to the large enrollments of the class or due to time constraint issues. In these cases, we provide written case study descriptions to the students based on past student or faculty projects. Students are then to analyze the case study, suggest problems with the system, and propose solutions. Students appreciate working with real issues, even though the case study experience is not as rich an experience as direct observation of a company.

The principal of *genchi genbutsu* provides the student with useful discovery learning experiences. However, simply presenting experiences is not sufficient, either in the factory or in

the classroom: The student must learn how to analyze and benefit from those experiences. What is necessary is development of the student's or team member's problem solving skills. As mentioned earlier, a key element of Lean is effective problem solving: "find a problem, fix the problem, and then keep the problem from coming back". Students must understand how to be effective problem solvers.

Within a factory, "finding a problem" is facilitated by systems that make problems and wastes evident in a factory. Visual management techniques, poke yokes, and Andon cords are all systems taught as part of Lean to bring attention to problems. In the frequently used analogy of the ship sailing over rocks, Lean's often-noted low inventory levels are even presented as a tool to identify problems.

Once the problems are evident in a lean system, a variety of techniques are used to identify relationships and determine root causes. These methods include Ishikawa fishbones, Five-why's, and many others. Once root causes are found, countermeasures are put in place to capture what was learned from the problem and prevent it from coming back. The A3 Problem Solving Report is a method used by Toyota and others to document the problem solving approach and the countermeasures implemented.

The industrial problem-solving tools of lean are taught as content in our lean courses. These tools and the principles behind them are not just applicable to the factory – the student can apply these same problem solving techniques in other classes and in their life. Students learn Pareto analysis, scatter plots, cause and effect diagrams, root cause analysis, and other methods. They also learn one of the core values of lean that problems should be made evident so that they can be seen and then addressed.

We can also apply these problem-solving principles to the classroom itself. The first way is to implement measures that allow students to quickly identify when problems are occurring in their own learning. This is done through frequent assessments of student learning. For example, short quizzes can be given weekly. Furthermore, during lectures, students should be engaged frequently through questions and discussions. This not only allows the instructor to identify problems in understanding, but it also establishes an open channel of communication to allow the students to notify the instructor of problems in his or her understanding (the equivalent of pulling an *andon cord* in a factory). Also, during simulated factory experiences (as discussed above), the simulation structure should be simple enough to allow students to collect data, determine problems, and implement and evaluate countermeasures within the permitted time.

It should be emphasized that the experience of the student in the process of problem solving is far more important than just knowledge of lean techniques or tools. The instructor should strive to practice the Socratic method: instead of telling the student solutions, the instructor should guide the student through the problem-solving process so that the student discovers the solution.

## 6. Emotional/Spiritual Support for Teams and Team Members

Lean manufacturing organizations like TMC have strong values embedded within their cultures.<sup>3</sup> The salient values are: openness, trust, concern for others, honesty, power sharing, and the ability to function in an environment where ambiguity is the norm; each activation of an andon signal (stop-the-line) introduces an element of ambiguity into the system.

Cognizant that new team members bring with them, into a lean environment, their learned sets of values acquired over a lifetime of conditioning<sup>3</sup>; the first job of leaders is to drive out fear according to Dr. Deming.<sup>4</sup> The new team member's experiences within the family, schools, institutions, and social cultures, in many cases, have socialized patterns of behavior that are incongruent with lean environments. These latent values are potential sources for high levels of anxiety and fear for new team members.

It is well known that fear limits learning ability in both animals and man.<sup>18</sup> Joseph Ledoux has argued that our emotions are the threads that hold our mental life together. Emotions define who we are to ourselves as well as to others. For example, anxiety and fear are close relatives; anxiety dwells within us as a result of previous fearful events and does not need an external stimulus as a trigger. Fear, on the other hand, needs an external stimulus—a snake in the grass. A rabbit that stops by his favorite watering hole only to encounter a red fox will not go near the watering hole in the future without experiencing a high level of anxiety.<sup>19</sup>

There is another dimension of the human that is defined as *spiritual*. The spiritual self can be either unconscious or a conscious, or some combination of both. Viktor E. Frankl argues that the fundamental characteristic of being human is its self-transcendent quality<sup>20</sup>; he argues the “*intrinsic fact that being human always relates and points to something other than self.*” Man is interested in *meaning to fulfill* and other human beings. Frankl stated his thesis this way.

*Well, if we investigate how the man in the street goes about finding meaning it turns out that there are three avenues that lead up to meaning fulfillment: First, doing a deed or creating a work; second, experiencing something or encountering someone; in other words, meaning can be found not only in work but also in love. Most important, however is the third avenue. Facing a fate we cannot change, we are called upon to make the best of it by rising above ourselves and growing beyond ourselves, in a word, by changing ourselves (Frankl, 2000).*

This is similar to Maslow's Needs Hierarchy: the basic needs are Physiological, Safety, Belonging, Self-Esteem, and Self-Actualization. If the lower levels of needs are met, then a person seeks to satisfy the higher needs. An organization that can provide support for each of these needs has a more satisfied employee.

Let us briefly consider these needs. Physiological and Safety needs are a basic requirement of a workplace. The Lean organization can help satisfy Belonging needs with collaborative teams and positive interactions with team members within the workplace. The Lean organization can help satisfy Self-Esteem needs providing

appropriate tools, training, and support mechanisms to allow employees to do a job well. The Lean organization can help satisfy Self-Actualization needs by providing meaningful work and meaningful problem solving that allows an employee to make a difference in the workplace and his world.

These same ideas translate in a perhaps an obvious way to the classroom. The instructor should express a genuine interest in the development and learning of his/her students. The environment should be one of open ideas that allow exploration of ideas in a discovery learning method. The students should be presented with the tools and material to allow them to be successful, and with expectations high enough that the students feel a sense of accomplishment and satisfaction. Finally, the students should understand that the material they are learning can have real impact on other people – as successful engineers and managers, they have the ability and responsibility for implementing good practices to create a positive work environment that is economically sustainable.

### **7. A Lean Systems Curriculum**

The processes for curriculum development, course development, designing the delivery system, and finally, designing a measurement and evaluation system are each highly specialized academic activities; each must be performed with an equally high degree of integration with each other to be effective. While, curriculum development, as an example, is a highly specialized function, it cannot be done effectively without some consideration for the individual course, or courses, that it will comprise. Additionally, the key direction in the design of a curriculum at the university level is the planned discipline of study of individual students. Conversely, at the business enterprise level, a curriculum is tied to the organization's strategies and operating plans; each strategy and operating plan must be assessed in order to identify the performance required of employees.

This section of this paper describes how the University of Kentucky college of engineering curriculum in lean manufacturing was developed as an integrated series of course offerings for undergraduate students and Masters Degree students in manufacturing systems engineering. The same series of courses is also offered to industry professionals as extension education offerings at a lower level of rigor; the study of the series at the extension education level provides a "certificate" for industry people. This section of the paper will outline the curriculum which we referred to earlier in the paper.

The credit versions of the lean systems courses are provided primarily for engineering graduate and undergraduate students. However, some non-engineering students (from business or medicine) have participated in the selected courses in the past. The first two courses, Principles and Practices of Lean Manufacturing and Lean Operations Management, are offered to both undergraduate and Masters Degree students. The remaining four courses, Organization Learning for the Lean Enterprise, Lean Value Stream Design, Management of a Lean System, and Leadership for the Lean Enterprise, are offered as Masters Degree elective courses in manufacturing systems engineering.

Our Lean program began in 1993. Through a partnership with Toyota, faculty at the University of Kentucky underwent repeated visits and training with Toyota. The first of the Lean credit courses was taught in 1994, and some courses have been taught regularly since that time.

In 2003, under a grant from Ford Motor Company, some of the courses were moved into a summer “boot-camp” format. This allows the students to take two courses simultaneously during a 4 week intensive summer session. Since no other courses are taken during each session, students are available for involvement throughout the day. This allows multiple plant visits, extensive factory simulation exercises, and team projects. Students indicate that the experience is very intense but worthwhile. Employers indicate a strong demand for the students, appreciating the students’ mixture of theory and application, and the mixture of both technical knowledge and soft-skills knowledge (organizational theory, leadership, and teamwork). In 2006, a grant from the Society of Manufacturing Engineers (SME) Engineering Foundation was awarded to extend the teaching methods to an even broader set of courses in the manufacturing systems engineering curriculum.

## **Curriculum of Courses**

### **Course 1: Principles and Practices of the Lean Production System**

*Course Abstract:* This introductory course provides fundamental concepts of production improvement using lean manufacturing principles. The course includes an overview of lean methodologies such as standardized work, JIT (Just in Time), 5S, visual management, zero defect quality control, setup reduction, continuous improvement (kaizen) and various other related topics. Knowledge of lean principles and philosophies allow the student to understand the benefits of lean manufacturing and avoid common pitfalls lean operation. This course consists of a combination of lectures, videos, hands-on manufacturing simulations exercises, problem assignments and projects drawn from industry.

### **Course 2: Lean Operations Management**

*Course Abstract:* This course provides detailed structures and processes of operations management at the business unit level, with emphasis on value stream management. Basic structures are illustrated by a definitive simulation and hands-on continuous improvement activities. Content and process of operations management will flow from the executive level to the lowest level of operations. This course presents the foundational concepts of “lean” systems: contributions of Henry Ford, Dr. W. Edwards Deming, and general systems theory; this is followed by extensive analysis of operations management practices and their effects on production, productivity improvement, and quality. Knowledge of lean operations management prepares a manager to face the competitive challenges in managing organizational resources for achieving his/her quality, cost, and delivery objectives. Various case studies, simulation exercises, and role play activities will be utilized as media for presenting the course learning objectives.

*Team Project:* A team structure is organized and maintained throughout the course. Each team of four to six team members develops a strategy for transforming a traditional structure into a lean operations management structure. A case study is provided to each team by the instructor to be analyzed by the team.

### **Course 3: Organization Learning for the Lean Enterprise**

*Course Abstract:* The focus is on learning as a normal part of work. Lean enterprises continuously seek to learn and improve all processes to contribute value to their customers. The student will be able to articulate the role of lean thinking in the lean transformation and investigate the structures that guide behavior, and build the cultural foundation for sustainable change. Instructional strategies and learning theories are foundational principles for this course material.

### **Course 4: Lean Value Stream Design**

*Course Abstract:* This course presents the improvement of the value stream using broad (total system) and workstation (cell-level or process level) analysis. Various topics are covered, including process mapping, value stream mapping, advance pull techniques, cell layout design, facilities design, motion economy, and techniques for analyzing flow. The course presents the methods of developing a current state map that reveals the most significant sources of waste. Improvement techniques and guidelines are explained to develop a future state of the operation that shortens the overall product lead time. The course explains how to apply guidelines for cells, machines and materials. Total system (facilities) design is also reviewed in the understanding of dock-to-dock flow of materials, information, and people.

### **Course 5: Management of a Lean System**

*Course Abstract:* This course demonstrates how management skills for supervision, group leaders, and team leaders within a lean production system are applicable to hospitals, research centers, and offices. Through a series of self-guided exercises, discussions, and system simulations, participants learn how to build stability into organizations. In this challenging course, students build teams to solve the problems encountered in the simulation; build their own vision statements; explore what motivates them and their willingness to change; and develop strategies for applying what they learn in the workplace.

### **Course 6: Leadership for the Lean Enterprise**

*Course Abstract:* On the basis of a comprehensive prototype of the lean business system, this capstone course surveys proven leadership models and applies them to the lean enterprise, creating the appropriate balance of strategic and operational controls. It equips lean champions with the organizational and behavioral tools to manage sustainable change and tests their learning. Focus areas are: collaborative structures, learning and teaching, dynamics, organization structures, and the importance of inquiry learning dynamics.

## 8. Summary

This paper outlined some principles that are used within Lean manufacturing. We argue that the ideal of Lean manufacturing is a continuous-learning organization, with appropriate strategies that allow the organization to continuously learn, and thus continuously learn. We furthermore claim that the same structures and practices that establish a workplace as a learning environment can also be translated to the classroom.

We do not claim that the strategies presented above have previously been restricted to the industry setting, or that they are necessarily “new” within a university setting. In fact, many of the items that we discuss above are already common practice of good instructors in many disciplines. Our aim here is to point out the parallels between good instructional practice as used in a learning organization, and good instructional practice as used in a learning classroom. By recognizing and acknowledging these parallels, an instructor of good industrial practices can reinforce and model those practices for his/her students through the classroom.

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