Teaching Lean Manufacturing Principles Using an Interdisciplinary Project Featuring Industrial/Academic Cooperation

Robert Van Til1, Sankar Sengupta2, Gene Fliedner3, Monica Tracey4 and Kevin Yamada5
Oakland University
Rochester, MI 48309

Abstract - Faculty from Oakland University’s engineering, business and education schools are working together with Oakland’s Pawley Institute to teach students about lean manufacturing using an interdisciplinary approach. The goal is to educate future employees about lean from a diverse perspective before they enter the workforce. By providing students with the knowledge and skills to use lean principles and tools to solve real world problems, these future employees will add immediate value to the companies that hire them. These Oakland University faculty members have developed an interdisciplinary course entitled “Lean Principles and Application.” This elective course is taken by students enrolled in engineering, business, and human resource development degree programs. A key component of the course is a semester long project that involves analyzing the performance of a local manufacturing company and developing a plan for implementing a lean program. Interdisciplinary teams of students work on the project with company personnel.

Index Terms – Lean Manufacturing, Industry Partnership, Interdisciplinary.

INTRODUCTION

The principles and concepts of the Toyota Production System (also know as lean manufacturing) such as the total elimination of waste and continuous improvement (kaizen), are being used by more business to better compete in today’s global market, [1] and [2]. In one of the most competitive industrial markets, the automotive industry in North America, the effective application of lean manufacturing techniques is helping to improve performance, [3]. As a result, there is a greater need for employees who are able to participate in, as well as lead, the necessary changes to existing cultures, business operating systems and operational practices in order to achieve world class manufacturing status, [4].

Typically, organizations that utilize lean practices as a function of their continuous improvement philosophy invest a large amount of time and money to continually educate all employees, [5]. But there is a cost associated in continually training employees, there is also an impact on the business due to taking people away from their normal work duties during training [6]. In addition, lean practices are not entirely imbedded in the U.S. workforce or in the knowledge base of its future workforce, [7].

In 2002, faculty from Oakland University’s School of Engineering and Computer Science, School of Education and Human Services and School of Business Administration met with personnel from Oakland’s Pawley Institute to begin developing an interdisciplinary course on lean. The mission of the Pawley Institute is “to give Oakland University, its students and graduates a competitive advantage through education, research, and the application of lean principles and practices”.

This course was designed for students in Oakland University’s engineering M.S. programs (computer, electrical, mechanical, and systems), MBA program and Masters in Training and Development (MTD) program. Hence, the focus of the course concerned the application of lean concepts across the entire enterprise, not just the manufacturing environment. The course is entitled Lean Principles and Application and is cross-listed in all three schools.

Lean Principles and Application was first taught during the 2003-04 academic year and has been offered twice. The class in limited to 24 students, eight from each of the three programs. The course is team-taught using faculty from each of the programs and incorporates presentations by lean practitioners from industry. An overview concerning the development, structure and content of the Lean Principles and Application course is presented in [8].

A major component of the lean course is a semester long, team-based project involving a partnership with a local manufacturing company. The focus of this paper concerns the development and implementation of this project.

1 Robert Van Til, Professor, Industrial & Systems Engineering Dept., School of Engineering & Computer Science, vantil@oakland.edu
2 Sankar Sengupta, Associate Professor, Industrial & Systems Engineering Dept., School of Engineering & Computer Science, sengupta@oakland.edu
3 Gene Fliedner, Associate Professor, Decision & Information Sciences Dept., School of Business Administration, fliedner@oakland.edu
4 Monica Tracey, Assistant Professor, Human Resource Development Dept., School of Education & Human Services, tracey@oakland.edu
5 Kevin Yamada, Executive Director, Pawley Institute, yamada@oakland.edu
DEVELOPMENT OF COURSE PROJECT

The course development team (the authors of this paper) constructed the following criteria for selecting a company partner for the lean course project.

1) A receptive management and workforce that will allow student teams access to shop floor processes, material flow, information systems and data in addition to allowing minor disruptions to normal work activities.

2) Existing opportunities to apply lean concepts and practices based upon the current state of the company’s lean transformation, work activities and processes.

3) A desire to participate in a win/win relationship based upon the students learning more about lean through real world application and the company benefiting from the close examination of its current state processes as well as from the ideas and recommendations for improvement generated by the student teams.

After the course development team visited several companies, NuStep Inc. of Ann Arbor, MI was selected as the host company for the project. NuStep is a small, privately-owned company that manufactures a rehabilitation product called the TRS 4000 Recumbent Cross Trainer that is used in therapy/fitness centers, hospitals and cardiac clinics.

PROJECT – YEAR ONE

Cross-discipline teams comprised of six students each were established early in the course. Team membership was selected by a random drawing from each program. Hence, every team contained two students from each program. The objective was to form a team with diverse skills, not unlike teams of employees that typically work on continual improvement activities.

The four teams were each assigned a team specific problem statement as well as two common class-wide problem statements. The problem statements were developed with the input and concurrence of NuStep’s management personnel.

The four team-specific problem statements were as follows.

1) Develop a plan to implement systems thinking throughout the manufacturing system. Determine sources of variation and implement statistical process control wherever they are applicable in the manufacturing system.

2) Develop a plan to minimize variation as well as to predict dimensional accuracy and throughput of robotically welded components.

3) Design and implement a kanban controlled reorder system for material flow between the fabrication and assembly departments.

4) Develop a plan to implement lean thinking and systems throughout the manufacturing system.

The common problem statements given to each team were as follows.

1) Estimate the current capacity (throughput and quality) of the manufacturing system and make recommendations to improve throughput.

2) Develop a plan to effectively train the workforce in lean principles and create a culture centered on process thinking and continuous improvement.

A nominal amount of basic information related to NuStep’s history, product, manufacturing processes and business processes was provided to each team. The teams were then tasked with data collection and analysis in order to develop their solutions.

The class, including faculty members, made two all day site visits to NuStep’s manufacturing facility. Some team members also made a third visit to NuStep to collect additional data. Formal team presentations were made on the last day of class to the other teams, faculty and NuStep personnel as well as representatives from the Pawley Institute and lean practitioners from local industry.

Evaluation of the teams’ project report and presentation accounted for 40 percent of each student’s grade and was based upon the following criteria.

- Quality of the current state value stream map generated by the team.
- Value analysis as well as wastes identified, quantified and documented by the team.
- Lean principles incorporated in the team’s solution.
- Quality of the team’s solution as measured by potential impact on throughput and cost.
- Quality of team’s presentation and interaction with the audience.

RESULTS AND ASSESSMENT – YEAR ONE

In general, course faculty and NuStep management personnel were pleased with the solutions presented by the student teams. Several sources of waste in NuStep’s manufacturing system were identified and suggestions for reducing them were presented. But due to the limited constraints contained in the problem statements, many of the teams’ solutions were unrealistic for NuStep to implement. The implementation of these solutions tended to require large capital outlays as well as significant downtime of the manufacturing system.

In order to assess the course, students were presented a survey at the end of the semester. Four of the survey
questions concerned the project. These questions are listed below followed by a representative selection of the students’ replies.

1) List ways in which the project was useful.

• Experience with real world project. Networking, interacting in a group that is cross functional. Identifying the realities of manufacturing in the local environment.

• It hasn’t been useful yet at the end of the class when we can see everyone’s ideas it will be very valuable.

• I have learned a lot while working on the project, especially with the visit to the NuStep facility. However, I’ve learned either from my group members or on my own, which is fine except that it seems that I should have been learning at least a little from the professors. I found the lack of guidance and inaccurate answers to questions very frustrating. I still am not sure what is expected as the end result for this project.

• The project has simulated how teams work in the corporate world. My fellow team members introduced me to new ideas and offered new perspectives on issues. I am accustomed to working with HRD students who have all been taught the same material as myself, so they think the same way I do. It was interesting to work with people who don’t understand the relevance importance of HR and training. I had to learn to introduce ideas in a different way, rather than use HR vocabulary. I believe that this experience has taught me how to better communicate with others, learn to accept criticism and learn from others.

2) List ways to improve the project.

• Students learn current state value stream mapping before going to NuStep. Students need to know 8 kinds of waste before going to NuStep.

• Our team wasted a lot of time in the beginning because we thought it was necessary for all members to work on all tasks as a team. We worked more cohesively as a group once we concentrated solely on our individual areas of expertise and presented our individual ideas to the group. I think that teams in the future should be instructed to separate tasks amongst the team into areas of specialty, experience, and education.

• Teach what is needed before going to NuStep. (lean principles, value stream mapping, 5S). NuStep needs to be prepared with the inputs required to solve the problems assigned.

• Reinforce principles taught prior to sending students to the customer (i.e. give them a macroscopic lean lecture from every college in the first four weeks).

• More guidance and direction.

• Directions before entering the plant. A few helpful hints as to what the team should do and look for suggesting learner and business students focus on processes while HR focus on people and culture. The second visit was better because we were focused but it probably could have been avoided if we knew what to focus on for the first visit.

• Need the skills before we go (value stream mapping, data collection tools, examination of problem-statement). All instructors must be present at every class. Data must be present. Explanation of data. Weekly check-ins with instructor from program area. 4 groups must interact holistically.

3) What class would you have liked to have before visiting NuStep’s plant?

• A class on current state mapping.

• The MPS and MRP overview would have been helpful. I’m sure some of the engineering info but hard to say since we haven’t had it yet.

• Info from each college from a macroscopic level.

• Value-stream mapping and some examples of lean transformations from literature.

• 8 wastes, VSM

4) Additional comments concerning the project.

• Break the overall problems that NuStep faces into smaller steps that can be accomplished within the term. Allow the groups to select from the problem list?

• More time with the “Lean systems and tools” would be helpful. Help us learn and recall 8 wastes and results of each. 5S’s and examples of each. Definitions of lean. Lean rules and principles. In addition, directions for the project, discussion on how we should interact with the managers and employees. Basics of lean. The focus is at different levels. We need definitions and concepts of lean, a few tools, how to diagnose what and why those wastes exist, possible solutions and steps for implementing lean with the understanding that each company is a little different so the approach might vary while the concept of lean remains the same.
The project should not be used as a grading criteria. Instead just used as a teaching/learning tool. Project has put too much stress and has taken away from actually learning lean, but more emphasis and stress on figuring out whether to work on the lean paper assignment or finish project by the deadline. This is especially hard when students are taking 2 courses and work full time.

**PROJECT – YEAR TWO**

Following the lean principle of continuous improvement, a kaizen [1] of the course was conducted by the faculty teaching the course. The kaizen team reviewed feedback from NuStep personnel and guest lecturers (primarily from industry) as well as the student evaluations.

As a result of this kaizen, the course project was modified as follows. First, an increased focus on lean concepts was incorporated into the project. In addition, the project was organized so each team received the same problem statement, but had to develop a solution for a different portion of NuStep's manufacturing facility. Finally, the economic constraints were clearly presented in the problem statement.

Due to scheduling conflicts, only 16 students enrolled for the second class. The class was divided into four teams. Three of these teams contained members from each of the three programs. Since only three Masters in Training and Development (MTD) students enrolled for the course, the MTD students also comprised a fourth “MTD” team. This allowed the MTD students to work as a team to address human resource problems identified by their interdisciplinary team.

NuStep’s manufacturing facility was divided into three separate cells as follows.

**Cell A**: vertical saw, CNC milling center, tube bending

**Cell B**: laser cutter, press brake, inspection, powdercoat system, robotic welding

**Cell C**: final assembly

Each interdisciplinary team was assigned a cell. As in the first project, this problem statement was developed with the assistance of NuStep personnel. The problem statement for each interdisciplinary team was as follows.

1) In your assigned cell, identify, quantify, document any non-value added activities and/or related resources, and develop a plan and the associated tasks to reduce/eliminate them. *Hint*: To the best of your ability, start by utilizing the value stream mapping technique.

2) Consider all of the inputs, conversion activities, resources and outputs for your cell. Identify and document the cost savings or any other advantages of clearly connecting to your supplier and customer, and operating to the cellular concept vs. the current state, if any.

3) Create a lean operating system (i.e., optimal manpower, materials, operator and machine times, standardized work, instructions/procedures, training methods and a visual environment) that will enhance flow based on actual usage or the rate of consumption of the customer.

4) Establish the pace of production for your cell in accordance with the operating system and based upon the concept of pull (i.e., producing no more than what the downstream customer uses or consumes). Identify and document the triggers, signals, quantities and system rules that will support this objective. All matters of implementation and sustainability should be considered and taken into account.

5) If capital expenditure(s) is required to address the statements above, calculate and document the Return On Investment (ROI) and Net Present Value (NPV) financial evaluations. This must be favorable for any significant outlay of capital.

**RESULTS AND ASSESSMENT – YEAR TWO**

Both the course faculty and NuStep management personnel believed the performance of the student teams improved over the first project. The solutions were more focused on continuous improvement, rather than recommending major redesigns of the manufacturing system as was common in the first project.

Student evaluations were transferred to the School of Engineering’s on-line course evaluation system during the second offering of the course. The students’ rating of the project was a 4.0 out of 5.0 (scale: 5-excellent, 4-good, 3-average, 2-poor, 1-unsatisfactory). Representative student comments concerning the project are as follows.

- Excellent. Bring the Real World in.

- It would have been helpful to also focus on QMS as that is what NuStep is striving towards and having some specific information on that topic would have been helpful. I ended up researching that on my own and asking the engineers in my group for clarification on this concept so I understood where NuStep wanted to be. Also, the course would have been more effective if time each week was allocated specifically to working in our groups.

- Course needs to be designed around visits to plant. Class time should be used each week to discuss the things going on at the plant. Prior to the visit should relate topics covered in class with processes in the plant.

- There needs to be much more structure before it begins. Deliverables must be clearly defined.
• Do more site visits; go to different facilities, larger manufacturing industries to see a bigger picture, use more than one main lean tool during the project.

• This was a great initiation to lean manufacturing. My expectations of what I was going to get out of it were overachieved.

• The opportunity to meet and work with the people at NuStep was THE BEST part of this class. I really enjoyed the time at the plant and the time spent observing and talking with the people there. They were the motivation to keep going and to try my best to evaluate where they are and make positive suggestions to help them reach their goals.

PROPOSED PROJECT – YEAR THREE
A kaizen of the course’s second year is currently underway. Tentative plans are to again use problem statements similar to that of the second project. In addition, a new industrial partner has been selected for the third project. One of the reasons for selecting a new partner is to ensure that solutions from the second project were not used again.

The primary reason for selecting a new industrial partner is to better integrate the project assignment with the lectures. The new partner’s manufacturing facility is located three miles from Oakland University. Hence, several of the lectures will be held at the industrial partner’s manufacturing facility. In addition, personnel from the industrial partner will attend these lectures.

The presentation format will also be modified. Rather that presenting the entire results from the project at the end of the semester, two presentations will be required. In the first presentation to be held mid-semester, the student teams will present their results concerning the current state of the manufacturing system.

As with the final presentation, faculty, personnel from the industrial partner, representatives from the Pawley Institute and lean practitioners from local industry will be in attendance. Hence, students will be provided with feedback concerning their understanding of the current state prior to developing recommendations for improvement. These recommendations will then be presented at the end of the semester to the same audience.

ACKNOWLEDGMENT
Partial funding for this effort was provided by Oakland University’s Pawley Institute. The authors would especially like to thank Dennis Pawley for his help in evaluating the student projects and meeting with the students to provide valuable feedback.

The authors would also like to thank all the associates and owners of NuStep Inc. including Norma Sarns, Richard Sarns and Mike Steiner for contributing to the education of our students.

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