AC 2010-1870: INTEGRATING HANDS-ON DISCOVERY OF LEAN PRINCIPLES INTO OPERATIONS, INDUSTRIAL, AND MANUFACTURING CURRICULA

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Integrating Hands-On Discovery of Lean Principles into Operations, Industrial, and Manufacturing Curricula

Abstract

The objective of this project is to develop hands-on curriculum materials demonstrated to improve students' ability to apply lean process design ideas and to use data to support decisions, and to create an effective model for their use in a variety of academic settings. While the principles of lean design are straightforward, designing an effective process is a creative activity that requires innovative thinking. Academic programs have been most successful in teaching the science behind lean, but less effective in providing opportunities and activities to support design.

To build on successful lean training programs in industry, the academic PI's are collaborating with a management consulting firm with expertise in developing lean simulation products and conducting lean training. In particular, in conjunction with a physical simulation that involves a clock assembly process, we are developing lean process design case studies to explore lean application in different settings and with more advanced tactics. These materials are being tested at 15 diverse universities, where we are assessing the effects on student and faculty learning.

Introduction and Project Goals

Lean principles provide systematic guidelines for designing effective processes, focusing on eliminating waste by specifying value, simplifying flow, and pulling from customer demand[7]. Lean ideas have transformed process design and significantly improved lead times, quality and cost for many manufacturing companies[2]. While lean principles are simply stated, the design process is complicated because every process has unique constraints and competitive drivers. To be effective designers, students need to be able to apply a variety of tactics used to achieve the principles, as well as understand when these tactics are likely to be effective. Although many educational programs expose students to lean topics in courses, limited opportunities are provided to practice application.

The goal of this project is to develop and implement hands-on curriculum materials to support learning of lean process design, through four objectives:

- **Create new learning materials** by developing 15 *Lean Process Design Case Studies* that are designed to complement a physical simulation where participants assemble clocks using a multi-stage process to get hands-on practice applying lean principles. The *Lean Process Design Case Studies* that have been developed to allow students to explore different applications (e.g., services, coordinating with small companies) and contrast the tactics used in different situations.
- **Develop faculty expertise** through experiential workshops to introduce materials, and by participating faculty with ongoing development opportunities to improve teaching through interaction with lean practitioners and opportunities to participate in developing case study materials. We held workshop in Summer 2007 and 2008 to explore basic lean principles, as well as a workshop held in Summer 2008 to explore application of lean principles through a supply chain simulation.

- **Implement educational innovations** by testing the curriculum materials at a variety of diverse colleges and universities, representing minority-serving institutions, and engineering and operations management majors.
- **Assess learning and evaluate innovations** at testing institutions, specifically the ability to apply lean principles and to use data effectively, in a variety of educational settings

To date, we have completed a variety of activities to support each of these objectives, and describe them briefly in this paper.

Project Activities

Case Studies. In Spring 2008, we developed an RFP to involve participants in case study development through grants provided by NSF funds. We reviewed submissions and selected participants based on a two-round review process in May and June 2008, which included having potential case writers participate in the case-writing workshop we held in June 2008. As a result, the following case studies were developed and are being reviewed and tested in 2009/10:

- A Home Healthcare Agency Goes Lean
- Leaning Performance Measures at Dayton Meters Industries
- Using Pull Replenishment to Minimize Spare Parts Inventory
- Getting Lean Along the Supply Chain: Applying Lean Principles and Evaluating Tradeoffs
- Wellspan Health
- Implementing Lean Administration in the Grand Rapids Public Library System
- Managing Lean Implementation Risks
- Lean Wake-up Call in Pass and Seymour/Legrand
- Setting up an Inventory Control Kanban System for Small Businesses
- Green Design: Implications for Lean Operations

Developing Faculty Expertise. The process for faculty development in the project has three components: workshops that introduce participants to teaching materials, follow up support during initial implementation provided through our management consultant partners, and opportunities to work on a product team to develop case studies. Because introducing classroom innovation involves faculty learning about both the materials and new teaching strategies, the sustained support offers multiple opportunities for feedback and discussion as well as opportunities to be actively engaged in creating new knowledge, a model that addresses important learning principles[5]. We held 4 workshops, 1 in June 2007 and 3 in June 2008, and also provided follow up support (see the *Implementing at Diverse Sites* section) and case study development opportunities (see the section entitled *Case Studies*). We developed materials to support wider recruitment efforts for the second year, including a brochure and website to that provide a short description of the project and the responsibilities of participants, and an application form and process for reviewing applications.

A summary of the workshops is provided below:

- Lean Enterprise Foundations workshop , June 25-27, 2007
  - 11 organizations, 24 faculty, students, professionals

    - Explore use of lean simulations, a high volume, limited variety setting and a simulation with greater product variety. Participants played roles in the simulations, and were introduced to support materials as well as the experiences of the PIs using the simulations. In discussion sessions, participants discussed teaching strategies, potential obstacles, learning objectives, and supporting materials (modules, case studies) for their educational setting.
- Lean Enterprise Foundations workshop , June 9-10, 2008
    - 13 organizations, 23 faculty, students, professionals
    - Explore use of lean simulations, as in the previous year, but condensed the session to two days based on feedback from the first year participants, who also suggested that more time be spent exploring how to include materials in their courses, and to how to use materials in the context of a university class (it is easy to fall into teaching lean rather than how to teach lean)
- Case Study Development workshop, June 11, 2008
    - 18 organizations, 28 faculty, students, professionals
    - This workshop was led by Dr. Janis Gogan from Bentley College, an expert case writer who has given similar workshops elsewhere.
- Lean Supply Chain workshop, June 12-13, 2008
    - 13 organizations, 22 faculty, students, professionals
    - Explore use of TimeWise^{TM} 104 (supply chain) simulation. In this workshop, participants played simulation roles, and spent time discussing implementation and understanding the simulation dynamics.

Overall, participants came from 22 different universities.

Implementing at Diverse Sites. From the schools who participated in the workshops, materials were used for the first time at 1 school in Spring 2007, 2 schools in Fall 2008, 3 schools in Spring 2008, 1 school in Summer 2009, 6 in Fall 2009, and 4 schools in Spring 2009, including implementations of both the basic lean and supply chain simulations in engineering and management courses. Of these universities, 11 were supported in their first implementation by a lean trainer from the management consultant (or in one case, one of the PIs). The remaining 6 preferred to implement without additional support; generally, this occurred at universities where more than one faculty member attended the workshop and there was 'built-in' support. Four remaining schools are planning implementations in 2009/2010, while we will continue to focus on schools that have already implemented to ensure materials continue to be used and to examine sustainability.

Assessing Learning and Evaluating Innovations. To support evaluation of the project, we developed a survey to examine student attitudes about their lean learning, as well as several problems that could be used to assess student abilities related to applying lean ideas, and a faculty journal to better understand and improve the faculty development process. We are interested in topical knowledge as well as the level of mastery, as defined by Bloom's taxonomy[1]. Rubrics and coding standards are being developed to ensure reliable assessment[3,4].

These tools were used at implementing schools with appropriate approval; data continues to be collected and analyzed as the project progresses.

Conclusions

We have been active in disseminating the results of the project, both directly by the PIs as well as by encouraging participants to present their experiences and findings. To date, the project has resulted in 12 presentations by the PIs at conferences or seminars, 5 presentations by participating faculty, 2 conference proceeding papers, and 1 journal article.

In addition, the project has impacted over 1,000 students across the participating institutions, where the benefits of using such an active approach were summarized by one faculty member using the simulation who noted:

> "I was surprised at how much freshman got from this simulation. They had fun doing it, but all of them were able to evaluate past jobs and give very specific lean changes that would have increased their efficiency. I think this training will open up internship opportunities as well. My students would never have learned as much from a lecture format."

The project also seeks to generate greater understanding about what students learn, and how such simulations might impact the ability to design effective processes and use data efficiently. Our initial results are consistent with other studies that show students' design and problem-solving abilities are improved in courses that use active and collaborative learning[6]. The cross-site comparison also allows exploration of the correlation between the time spent on the simulation and student learning.

Another goal of the project is to create an implementation model that supports sustained use of the learning methods. Because simulation logistics require preparation on the part of faculty members, and experimentation can require additional class time, it is easier to lecture. Demonstrating learning benefits is critical for generating faculty enthusiasm. Initially, it is also important that faculty feel comfortable leading the simulation; the'Train-the-Trainer' workshop, on-site support during the first run of the simulation, and the simulation documentation all contributed to the initial implementation success. As the project continues, we will examine the importance of ongoing support, reflective activities such as writing articles, and opportunities to participate in case development as ways of keeping faculty engaged to sustain changes.

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