

The LAI Lean Academy Experience: Introductory Lean Six Sigma Curriculum

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Abstract

This paper reports on a decade-long undertaking to develop and widely deploy an introductory Lean Six Sigma curriculum. The origins, objectives and history of the effort are summarized, as is the content of the core three-day short course. Versions of the curriculum have been offered to over 1600 participants in 60 short course and semester long subjects taught by 45 different instructors in the US and Latin America. Over 180,000 visits have been made to the curriculum posted on MIT's Open Courseware. Findings on the learning outcomes are presented based upon the extensive database compiled from student feedback and self-assessment.

Keywords

Lean enterprise, lean healthcare, lean product development, lean curriculum

1. Introduction

Education and training of the workforce are essential enablers for the transformation and sustainment of any enterprise. Enterprises often develop their own internal training, and may partner with local or national educational institutions for development and deployment of curriculum relevant to their current and future needs. In this paper we report on a ten year undertaking to develop and deploy curriculum in the basics of lean thinking for audiences from multiple academic, industry and government enterprises spanning college through continuing education and training. Although measuring the success such an effort is highly subjective, instructor experience and student feedback indicates that participant expectations were met or exceeded. This paper reports on what was done, why it was done, and what has been learned from this interesting undertaking.

In December 2000, General Lester Lyles, who was then head of the US Air Force Material Command, addressed the Lean Aerospace Initiative (LAI) Executive Board. The LAI (later to become the Lean Advancement Initiative) was a consortium of industry, government, and labor union members funding MIT to help research and enable implementation of lean thinking in the aerospace sector. After noting the great progress being made on research and implementation of lean thinking in the defense aerospace sector, he remarked that current and future college graduates needed basic education in this topic. His remarks were captured in the following directive from the Executive Board to the LAI program leadership, which the lead author directed at that time:

“A curriculum should be developed so that lean principles could be taught at key universities, businesses and military institutions across the country and be used for training new members of the acquisition community”

A directive this broad and coming without resources posed a considerable challenge.

LAI’s response was to form an Educational Network (EdNet) comprised of universities with faculty that shared the objective of this directive, and who were interested in pooling their resources to develop and deploy basic lean thinking curriculum. Each EdNet member signed a No Cost Collaborative Agreement with MIT, pledging to share intellectual property and agreeing to some basic governance principles. Initially there were 6-8 US members. By 2013 there were 70 member schools with 50% being international.

At their initial meeting in March of 2003, the EdNet members agreed to collaborate on developing a “Lean 101” short course, and deploying it as quickly as possible to audiences of summer interns in the LAI member organizations. The approach would be for faculty to pool their knowledge, instructional exercises, exhibits and time to develop a common course which they would then collaboratively teach each summer. Each faculty member would integrate this curriculum, or fragments of it, into their campus offerings in whatever way made sense to their local situation. The course would be five days in duration to give about the same contact hours as a semester on campus. The first offering was to 20 summer interns at Rolls Royce Indianapolis in June 2003. By the end of 2012 there have been 60 courses offered to over 1600 participants in four countries involving 45 instructors from 27 institutions. This rest of this paper presents an overview of this undertaking, a summary of the main course, and what has been learned from the experience.

2. LAI Lean Academy Overview

The principles and tools of lean thinking emanate from actual practices observed in organizations that strive for customer satisfaction, continuous improvement, worker involvement, and respect for people. John Shook of the Lean Enterprise Institute depicts the appropriate roles of classroom and On the Job Training (OJT) or On the Job Doing (OJD) for lean learning, as shown in Figure 1 [1]. Basic lean knowledge is best gained in the classroom. This can provide scaffolding for building one’s knowledge through more experiential OJT learning. Higher levels of ability can be aided by classroom experiences, with decreasing effectiveness for increasing learning levels. Classroom curriculum and pedagogy requires appropriate experiential content to contribute to higher levels of ability. Although Shook’s figure appeared well after the LAI Lean Academy effort started, it accurately portrays the underlying philosophy of the curriculum, which is learner centric and rich with experiential learning content.

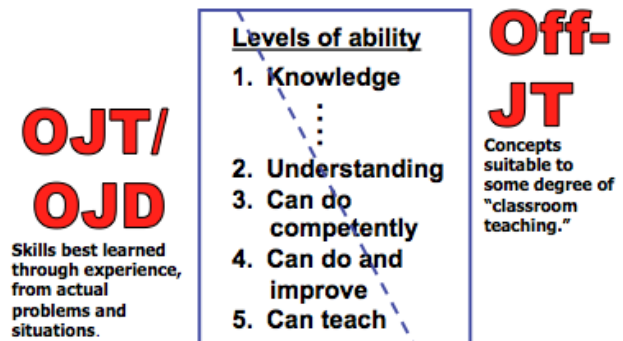


Figure 1 - Lean learning levels [1]

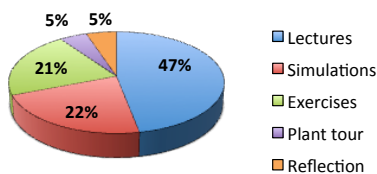


Figure 2 - Time allocated to various learning modes

The core of the LAI Lean Academy curriculum is a day-long Lego™ aircraft production simulation that provides a carefully designed “practice field” to apply lean principles for improving enterprise performance. Outcome data presented in Section 4 supports the learning effectiveness of this hands-on experiential representation for grasping and applying the basic lean thinking concepts and tools. Other modules in the course introduce various lean concepts, some of which are applied in the Lego simulation and others that are not. Through experience with various versions of the curriculum, it was found that a 50/50 mix of active learning and didactic lecture material provided good learning outcomes. The overall time budget for the current version of the course presented in

Section 3 is shown in Figure 2. Other than the Lego simulation, active learning content of modules ranges from 33% to 66% of the contact time. The effectiveness of these simulations and exercises has been reported earlier by McManus et al [2, 3] and Candido et al [4]. Other best practices from the learning literature such as carefully constructed learning objectives and reflective assessments have been utilized throughout the course.

The LAI Lean Academy effort started soon after publication of *Lean Enterprise Value* [5] by the LAI team. In that work, the authors articulate that the application of lean thinking can achieve its full potential only if lean principles are applied across all enterprise functions. This finding drove the content of the LAI Lean Academy towards an enterprise perspective. There are many courses on lean manufacturing or lean supply chain management, but few on

lean enterprise principles. Being an introductory course, a careful balance needed to be struck between high level enterprise topics and lower level hands on tools and techniques to meet the needs of the intended audiences – college level students and professionals who had no prior Lean exposure. The curriculum resulting from the effort was branded as the LAI Lean Academy™ and trademarked for quality control purposes. The initial examples and simulations in the course reflected the aerospace basis of the LAI. As the course became more widely deployed the content was broadened. Starting in 2009, a thrust was initiated to develop a healthcare version. The current version of the course covered in Section 3 is a balance of healthcare and aerospace with examples from other fields when appropriate exhibits or exercises can be found. The course has proven effective to a wide range of audiences.

2.1 Evolution of the LAI Lean Academy

Table 1 – LAI Lean Academy Timeline

2003	First LAI Lean Academy offered at Rolls Royce Indianapolis by 4 instructors to 20 summer interns.
	First Train-the-Trainer course offered to 20 faculty and practitioners at Arizona State University.
2004	VALUE Self-assessment tool adopted.
	5 courses offered by 19 instructors to 110 participants.
2005	First offering on campus at University of Missouri Rolla.
	8 courses offered by 25 instructors to 228 participants.
	Curriculum imported by University of Iowa Evening MBA program.
2006	University of Alabama Huntsville and USC established as LAI Lean Academy providers.
	10 courses offered by 23 instructors to 289 participants.
	First offering through MIT Professional Education.
2007	Introduction of the LAI Lean Product Development course.
	5 courses offered by 9 instructors to 116 participants.
	First offering to MIT students. Lectures videotaped for deployment on Open Courseware.
2008	Course adopted by Northeastern University Industrial Engineering Dept. for seniors and grad students.
	5 courses offered by 7 instructors to 124 students.
	LAI Lean Academy deployed on MIT's Open Courseware.
	Course adopted by USC Industrial & Systems Engineering Department as senior capstone course and graduate Lean Operations course.
2009	First offering outside the US at Universidad Popular Autonoma del Estado de Puebla, Puebla, Mexico.
	LAI Lean Healthcare Academy first offered to 40 Veterans Administration employees and fellows.
	6 courses offered by 16 instructors to 174 participants.
2010	5 courses offered by 7 instructors to 92 participants.
	First offering of merged Enterprise and Healthcare LAI Lean Academy at MIT.
2011	First course offered in South America in Santiago, Chile. Curriculum translated into Spanish.
	One-day LAI Lean Healthcare seminar introduced to 35 Veteran Administration and IHI Fellows.
	7 courses offered by 11 instructors to 174 participants.
2012	Course offered to MIT Leaders for Global Operations students.
	9 courses offered by 13 instructors to 169 participants.

After a very positive outcome from the first offering in 2003, the instructors decided to aggressively pursue curriculum improvement and expanding the instructor corps to prepare for future summer offerings. During 2004 – 2006, yearly courses were offered in January for future instructors who would teach the course the following summer. These participants were then involved in improving the curriculum they would be delivering. Through developing and then teaching the course, they took ownership of the content and started to deploy it in their home institutions. Several of the LAI member companies offered the courses, mostly to their newly hired staff rather than to summer interns. A yearly Deming-type improvement cycle was established; leading to seven distinct versions of the course over the ten years it has existed.

There were two major changes that occurred in 2007. The first was numerous requests to shorten the course from five days to three. The second was LAI members' declining interest in offering the full course; instead, they favored using internal training materials (in some cases augmented by LAI materials). In addition, the many teams that had developed different parts of the curriculum led to inconsistencies in module organization, terminology, formatting

and fonts, and speaker notes. From 2007 to 2008, emphasis shifted to redevelopment and testing of a three-day course with consistency across all modules, full instructor notes, and examples broadened beyond aerospace. Deployment strategy shifted from LAI companies to campus venues, often led by instructors who had taught the courses during the first three years. The course was offered through MIT’s continuing education summer program to practicing professionals, and academics seeking access the curriculum. The course was offered to MIT students in January 2008, which made it eligible for posting on MIT’s Open Courseware the following year.

During 2009, a lean healthcare course was developed and successfully tested with an audience of 40 Veteran Administration professionals. This eventually led to a new version of the LAI Lean Academy, described in Section 3, which can be taught as separate or integrated Healthcare or Enterprise versions. 2009 also saw the first offering outside the US in Puebla, Mexico. Two years later, a full Spanish translation of the curriculum was made by Seminario Internacional and Universidad Católica de Chile.

By the end of 2012, versions of the LAI Lean Academy curriculum had been offered 60 times to over 1600 participants by 45 different instructors. The three authors have collectively instructed versions of the course 58 times, some as a team and many with other instructors. The Open Courseware website [6] had 184,376 visits in 3-1/2 years, with over 200,000 viewings of the module videos. Version 7 of the course described in Section 3 contains 600 PowerPoint slides with speaker notes, a dozen simulations or exercises, a video plant tour and several video lectures by enterprise leaders, as well as a full suite of instructor notes, course evaluation tools, and other supporting materials. The accompanying glossary has 105 entries for terms introduced in the curriculum. A full Spanish Enterprise version is available. The LAI Lean Academy has been taught as a three-day short course and a semester long campus course to audiences of up to 67 participants. A separate Lean Product Development course has been offered at MIT, and one-day workshop versions of the health care and product development courses have been tested. Intellectual property licenses allow the curriculum to be deployed for any non-commercial educational use.

2.2 VALUE and VALUE PIL Self Assessments

It quickly became apparent that a method was needed to assess and articulate student learning. Traditional graded assessment methods are not suitable for short courses, nor did the Six Sigma colored belt credentials seem appropriate. Instead, an easily administered self-assessment method was introduced, the Virtual Assessment of Lean User Experience or VALUE. A version called the VALUE PIL (Proficiency Index Level) was introduced for the healthcare option. Both follow the same methodology, but have some detail differences in the knowledge areas. The self-assessment is administered before and after the course. The tool is also suitable for measuring increased proficiency as the participant applies their learning in the workplace. However, it has not been possible to track this progress due to the dispersion of participants after taking the course. One attempt was made to get such data for participants all within a single company, but even that was not possible.

Table 2 – VALUE and VALUE PIL Proficiency Levels

UNAWARE	To have no exposure to or knowledge of....
AWARE	To have experienced or been exposed to....
READY	To be able to participate in and contribute to...
CAPABLE	To be able to understand and explain....
SKILLED	To be skilled in the practice or implementation of...
EXPERT	To be able to lead or innovate in....

Participant proficiency is divided into the six levels shown in Table 2. Five are akin to Shook’s five levels (Fig. 1). A sixth UNAWARE level was included to aid in pre-course evaluation. Advancing to higher levels of proficiency takes progressively greater exposure to, and experience with the subject matter.

The assessment is applied to knowledge areas representing clusters of the course content: twelve for the VALUE and ten for the VALUE PIL tool. The actual VALUE worksheet is shown in the Appendix. On the left are rubrics for each proficiency level. The right column displays knowledge area clusters and topics covered in the course. Three pages of instruction accompanying the tool were designed to help mitigate the possibility that participants might have deflated or inflated opinions of their proficiency. Outcome data from this self-assessment will be presented in Section 4.

The LAI Lean Academy assumes the participant has no prior knowledge, i.e. is UNAWARE. Learning objectives are designed for a participant to complete the short course with a proficiency of at least READY but not higher than CAPABLE. This is in line with Shook’s assessment (Fig. 1) that application is needed for greater proficiency.

3. LAI Lean Academy Curriculum

The curriculum progresses from introduction of lean fundamentals on day 1, to application of lean fundamentals on day 2, to quality and six sigma basics, an accounts payable case study, and implementation on day 3. Several concepts are reinforced throughout the curriculum: value stream mapping and analysis (VSMA); identifying and eliminating waste; continuous improvement Plan-Do-Study-Act (PDSA) cycles; data driven structured problem solving; respect for people; and that Lean is a journey.

3.1 Day 1 – Basic Lean Fundamentals of Continuous Process Improvement and Respect for People

The first day's topics cover: the origins and basics of Lean and Six Sigma; implementation examples from various sectors; the five fundamental principals of lean thinking [7] including various forms of waste; process mapping; VSMA; topics such as kanban, 5/6S, 5 whys, balanced work, takt time; relational coordination [8,9]; integrated teams, and more. The day includes a plant tour to see Lean in action. If the logistics overhead of this precludes the preferred actual tour, a video tour of the New Balance shoe factory in Lawrence MA is used.

Besides the plant tour, active learning includes: a short and effective 6S exercise in the opening module; analysis of a hot dog stand operation which includes process mapping, waste identification, takt time, cycle time, value added and non value added time, balanced work, and VSMA; an exercise on job satisfaction; and a team building class debate on early vs. “fast follower” adoption of lean. Emphasis is given to fundamental concepts and tools rather than training on a specific approach. This is illustrated in Figure 3 which shows hot dog stand process maps from four different teams, making the point that there is no “right way” to do the map. Overall, 47% of the contact time on the first day is devoted to active learning.



Figure 3 - Process maps for four different teams for the hot dog stand exercise.

3.2 Day 2 – Application of Lean Fundamentals with Lego™ simulations

The Lego simulation with accompanying lecture materials for the second day result in over 60% of the contact hours being devoted to active learning. The basic version of the course (called the Enterprise version) utilizes a Lego airplane production enterprise while the Healthcare version adopts clinics that treat Lego patients. The simulations are structurally similar. Participants are process owners and the simulation mechanics constrain them to achieve performance improvement through process improvement, rather than through personal heroism or gaming the system. Process capability is represented with sand timers, and variability is introduced through die rolls. In the first segment of each simulation, participants are given a poorly performing enterprise with multiple sources of waste and unbalanced work. After a round to learn the simulation mechanics, just-do-it improvements can be made using techniques such as 6S, standardizing, visual control, and some pure waste elimination. The second segment of each simulation utilizes VSMA and structured root cause analysis to redesign their enterprise process to eliminate bottlenecks and non-value-added steps. The final segment of each simulation addresses “enterprise” issues outside the immediate control of each group. For both simulations, budgets are allocated for process improvement options selected by the team from multiple possibilities, and metrics are tracked to monitor performance improvement.

During the enterprise Lego aircraft production simulation, 5-6 participant teams comprise four assembly plants at a single table, and a supplier representative who procures parts from a remote supplier located across the room. In the first 12 minute round, enterprises can only produce 1-2 aircraft (Fig. 4), even after simple 6S and process standardization improvement. Difficulty in getting the right parts at

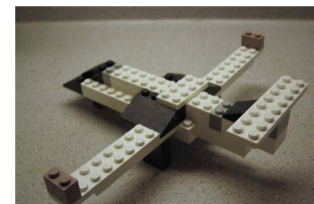


Figure 4 - Lego airplane

the right time leads into a 45 minute lecture and exercise on Lean Supply Chain Basics (kanban, paperless ordering, supplier involvement) which are then applied during the second segment, along with work rebalancing and standardization driven by a simplified VSMA exercise. Further improvement requires parts reduction which tees up a 45 minute lecture and exercise on Lean Engineering basics, emphasizing the point that only so much progress can be made before one encounters constraints external to one's part of the organization. Airplanes undergo a constrained redesign, and further efficiencies are introduced with balanced and standard work. In the final 12 minute round, enterprises produce 10-12 aircraft to meet customer demand. They and their supplier report on their financial performance as well as implementation lessons learned.



Figure 5 - Lego patients

Clinics of 5-6 participants process Lego patients (Fig. 5) in the healthcare simulation, moving them from registration through triage, examination, diagnosis and discharge. The color of patients' heads, torso and legs determine treatment pathways. Simulation mechanics are learned in the first segment and just-do-it improvements are implemented, but only 1-2 patients can be treated in a 12 minute round, even with allowed "overtime." Lecture material and exercises between the first and second segments cover structured problem solving based on Sobek and Smalley [10] and VSMA. Improvements are implemented and evaluated in the second simulation segment, but some patients remain untreated due to lack of diagnostic capability in each clinic. For the third segment, groups of clinics must work together as a healthcare system to treat all the patients, and a Lego version of electronic medical records are also introduced. Instructional

material on Rapid Process Improvement Workshops (RPIW) and Daily Management Systems provide the means to implement the needed process improvements. Networks of 2-3 clinics are able to treat 10 patients/clinic in the final round, without overtime or untreated patients, while reducing errors and patient wait times.

3.3 Day 3 – Case Study, Quality and Six Sigma Basics, Variation, and Lean Implementation

Day 3 provides an opportunity to explore several additional topics to further build the participants' understanding of Lean and Six Sigma. An opening module uses case study pedagogy to learn that VSMA, RPIW and other lean concepts apply equally well to office processes, using a real accounts payable processes from an LAI member company. The case study is quantitatively rich, which can be a difficult change of pace after the tactile Lego simulations the previous day. Two additional modules build upon the case study. One introduces A3 problem solving with an exercise to complete an A3 sheet for implementing the case study recommendations. Another module focuses on the impact of variation on throughput, using a dice and poker chip simulation of a variable, but otherwise perfectly balanced and linear, process. An equivalent computer simulation and queuing theory formula help deepen the participant's understanding of the impact of variation.

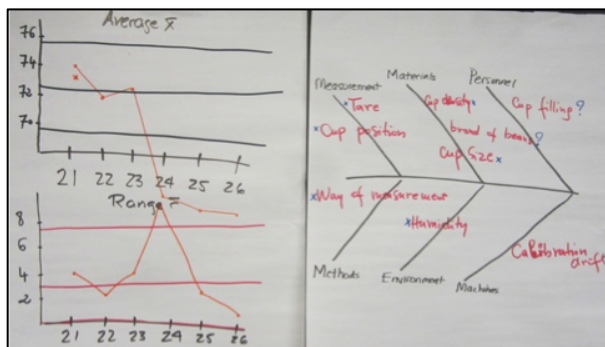


Figure 6 - Examples of control chart and fishbone diagrams from SPC exercise.

Finding the right level of depth for modules addressing quality and six sigma basics proved to be a challenge given the constrained amount of time available in a three day course. The final versions of these modules have been well received by beginners in these areas. Quality Tools and Topics uses a simple exercise to illustrate the difficulty of inspecting in quality, and then turns to the relationship of Lean and TQM before introducing the seven quality tools. Six Sigma Basics has an extensive statistical process control (SPC) simulation in the context of a pharmacy dispensing doses of a white bean "medicine." This rich, but facilitation-intensive exercise covers control charting and cause and effect root cause analysis (Fig. 6) in an engaging way. The day concludes with one or more

capstone talks from invited speakers, recounting their enterprise's lean journey. These talks are sometimes replaced with a video, although students generally find this much less engaging than the chance to talk to a real enterprise leader. Not including these talks, 52% of the contact hours on the third day are devoted to active learning exercises.

4. LAI Lean Academy Outcomes

The outcomes presented in this section are all based upon structured student assessments and feedback forms. As such, they represent the effectiveness of the learning as perceived by the students. Although there are limits to judging outcomes based on student assessments, the large amount of information that has been amassed over many offerings to multiple audiences is rich source of data.

4.1 Self-assessed Student Learning

VALUE self-assessment data (see Sec. 2.2) was collected since 2004 for all 3 and 5 day courses, on-campus semester long offerings, and two train-the-trainer versions. Each participant was requested to submit a pre and post course assessment for each of the 12 knowledge areas. Collected data was incomplete for some of the courses and was lost for others. However, even with that, a large amount of very useful data is available. Figure 7 shows the pre and post course results for 24 short courses. The pre-course response rate for this cohort was 92% and the post-course was 84%. Most participants completed the course with proficiencies in the READY to CAPABLE range, a statistically significant increase ($p < 0.05$) from their pre-course levels. Twelve percent of the participants assessed their proficiency at more advanced levels for some of the 12 knowledge areas.

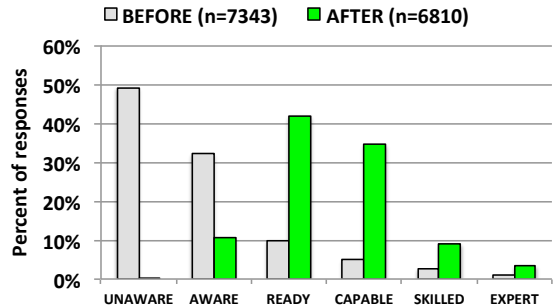


Figure 7 - VALUE proficiency responses for 24 three and five day courses to 674 participants.

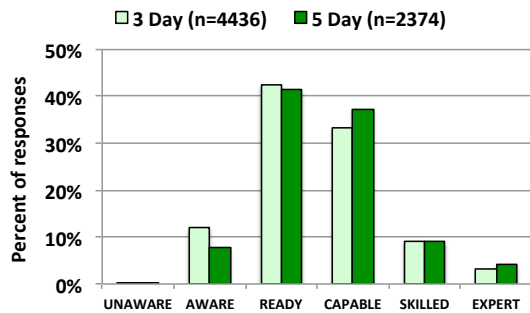


Figure 8 – Proficiency vs course duration.

Figure 8 shows the distribution of participant lean proficiency versus the length of the course. The differences are small and not statistically significant, indicating that with well-designed and tested curriculum, the three-day course is as effective as the five day one.

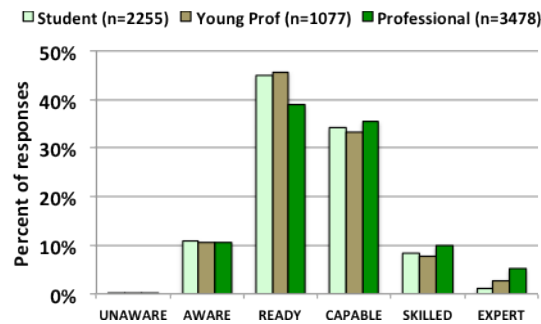


Figure 9 - Proficiency vs. cohort group.

One would expect that offering the same curriculum spread over a regular semester course would lead to deeper understanding and greater proficiency. Figure 10 compares outcomes for 6 semester offerings at USC, Northeastern, and MIT to 192 students with 8 short course offerings to 211 Rolls Royce interns, MIT and U of Missouri Rolla students. The semester long offerings were taught by veteran short course instructors, and had additional homework and project assignments. The statistically significant data ($p < 0.05$) shows that students perceived a significantly greater gain in proficiency from a semester long offering.

An interesting emergent finding was that the single curriculum proved equally effective for multiple audiences at different career levels, without tailoring the modules. Figure 9 shows the post-course efficiency for three different participant cohorts: undergraduate and graduate students; newly hired professionals with less than about three years experience; and professionals with many years of experience. The small differences are not statistically significant.

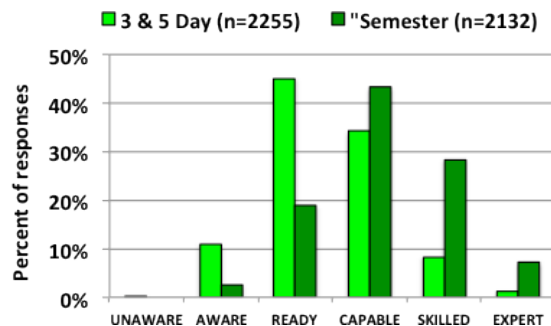


Figure 10 - Short course vs. semester outcomes.

4.2 Instructional Effectiveness

Students fill out a simple survey each day responding to the statement "The instruction helped me to achieve the learning objectives of the module," with possible responses of *Strongly Disagree*, *Disagree*, *Neutral*, *Agree*, and *Strongly Agree*. They are also asked for comments on "What could we have done better today?" and "What did we do really well today?" Survey results have been used to highlight problems, improve (or in some cases eliminate) underperforming modules, and identify successful instruction strategies. Some findings are discussed here based on survey results from all 18 three-day courses for which data was available. Of the 550 students in these classes, 97% provided data for at least one module.

Figure 11 shows the responses divided by various modes of instruction. The Lego™ simulations were judged to be highly effective. Lectures with varying levels of active learning content were judged less effective, but still excellent with about 90% of the responses in the top two choices. No correlation was found between level of active learning content and perceived module effectiveness. No statistical difference was found between students' reception of experienced based talks by experts and regular lecture modules, nor was any statistical difference found between hearing such talks by live experts versus hearing them on video. On the other hand, factory tours were perceived to be more effective than lectures at the $p < 0.05$ level of significance, while video tours were not. Figure 12 illustrates that students perceive the overall instruction to be more effective than professionals ($p < 0.1$) and young professionals ($p < 0.01$). This is not surprising given that they were the original targets of the course.

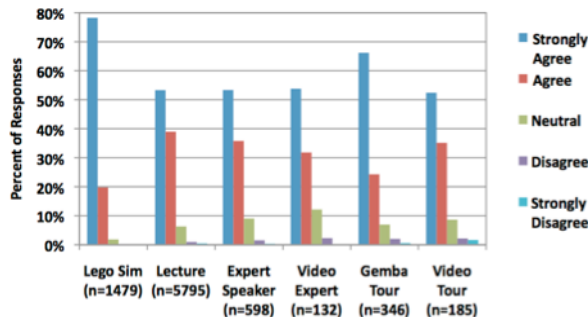


Figure 11 – Agreement that module helps achieve learning objectives, by instruction type.

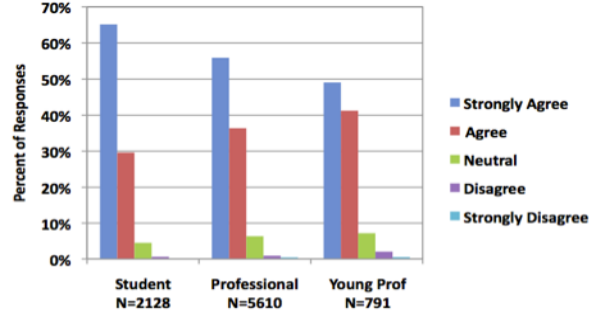


Figure 12 – Agreement that module helps achieve learning objectives, by cohort.

This data has been used as part of the continuous improvement of the curriculum. Figure 13 shows the aggregate effectiveness of the various modules, using the percent of *Strongly Agreed* responses as an approximate metric. This kind of chart is used to monitor the effectiveness of the modules and identify problem areas. Figure 14, which include data from the earlier 5-day version of the class, tracks the performance of an individual module (the VSM module) over time. The VSM module was selected for this illustration as it was found to be a difficult subject to teach in limited time, and was continuously worked on by the instructors in the early years of the academy. Improvements are seen from 2005 to 2006, when more time was dedicated to the subject, but in 2007 it was disrupted by compression of the material into a 3-day format. This was successfully overcome by a retooling of the module around an active learning exercise. The trend since then has been a steady decline, indicating the module may now need a refresh.

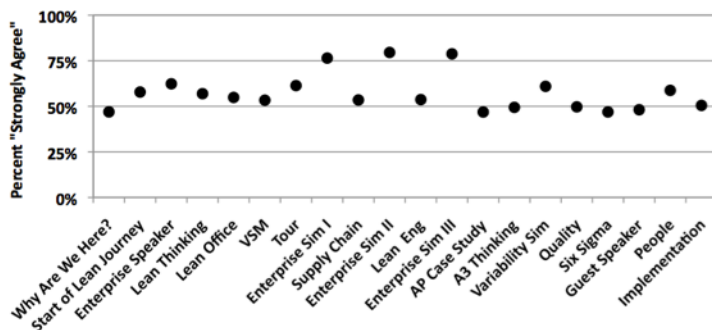


Figure 13 – Tracking of module effectiveness (N=196-597).

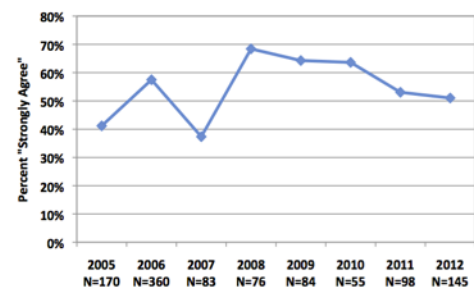


Figure 14 – VSM module effectiveness over time.

5. Summary

This paper summarizes a decade-long undertaking to develop and widely deploy introductory Lean Six Sigma curriculum. A 2001 directive from the Lean Aerospace Initiative Executive Board to accomplish this was met by engaging a large number of academics and practitioners in the LAI Educational Network. Various versions of curriculum they developed (Enterprise, Healthcare and Product Development) have been offered to over 1600 college through professional participants during 60 short courses and semester offerings in the US and Latin America taught by 45 different instructors. The core three-day curriculum is comprised of a dozen exercises or simulations, 600 PowerPoint slides, a case study, several videos and a robust set of instructor notes and supporting materials. The Enterprise version of the curriculum presented in this paper has been translated into Spanish. An earlier Enterprise version posted on MIT's Open Courseware has had 184,376 visitors in 3-1/2 years.

Student self-assessments of lean proficiency before and after the course as well as feedback on each module provide a large database to extract findings from this undertaking. These can be useful for future curriculum development, including those directed towards online versions. Highlights from the presented findings include:

- An overall 50/50 mix of active learning and didactic lecture contact hours provided effective learning. Some exercises may be easily adapted to online delivery, and could possibly be enhanced with larger audience participation such as through instantaneous class polling or self-organized local study groups. However team simulations using Legos or other physical devices and live plant tours will be a challenge for online learning. Yet they have proven to be the most effective of all the learning modalities employed.
- Student lean proficiency after completing the short course achieved the targeted level based upon the learning objectives, and adequately prepared them for participating in lean improvement projects in their current or future employment. The post-course proficiency was statistically the same for both the current three-day course and the original five-day course. Post-course proficiency was statistically the same whether the participant was an on campus undergraduate or graduate student, a recent graduate, or a seasoned professional.
- Versions of the course offered on campus over a full semester with additional homework and projects lead to statistically significant greater post course proficiency, as would be expected. Data presented provides a quantitative measure of this increased learning. This data might be valuable to those deciding whether to offer or take a short course versus a semester course for credit.

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Appendix – VALUE Self Assessment Worksheet



LAI Lean Academy® VALUE Worksheet

LEVEL 0 – UNAWARE:

To have no exposure to or knowledge of

- Have I never heard about these topics at all?
- Have I only heard about these topics in casual conversation?

LEVEL 1 – AWARE:

To have experienced or been exposed to

- Have I had some organized introduction or instruction to these topics?
- Have I used some of these topics in my work?
- Can I tell myself what these topics really mean?

LEVEL 2 – READY:

To be able to participate in and contribute to

- Do I know enough about these topics that I can comprehend what other people mean?
- Can I participate in give-and-take dialog on these topics?
- Have I ever participated in an event when this topic was used?
- Did I contribute to the discussion or action surrounding this topic?

LEVEL 3 – CAPABLE:

To be able to understand and explain

- To whom could I explain these topics?
- What would I actually tell them?
- Have I ever actually explained any of these topics to someone else?
- Have I written something about these topics?
- Have I given a presentation where I explained these topics or needed these topics to explain about a lean activity?

LEVEL 4 – SKILLED:

To be skilled in the practice or implementation of

- Have I applied my knowledge in this area? How did I apply it?
- Was I able to improve enterprise value creation by applying my knowledge in this area?
- Have I applied my knowledge more than once?
- Did I learn new things about this area by applying my knowledge?

LEVEL 5 – EXPERT:

To be able to lead or innovate in

- Have I ever lead a lean activity in this area?
- Have I taught someone else about these topics?
- Have I discovered new knowledge that has improved lean practices in this area?

LEVEL KNOWLEDGE AREA

- Context for Lean implementation:** External factors driving change; transformation challenges; demonstrated benefits
- Definition of Lean:** Definition of lean thinking; customer value; Gemba
- Process concepts:** inputs, outputs, process elements; process maps; lead & cycle time; capacity; throughput; balancing
- Five fundamental principles of Lean Thinking:** value; mura, muri, muda; 8 wastes value streams; flow; pull; perfection
- Lean tools and concepts:** VSMA; 6S; 5 whys; 8 wastes; single piece flow; andon; kanban; kitting standard work; balanced work; Genschi Genbutsu; takt time
- Lean office principles:** identify and apply lean thinking and analysis tools to office processes
- Lean engineering principles:** product lifecycle; IPPD, info wastes, PDVSM, DFMA, tools for lean engineering
- Lean supply chain management principles:** suppliers as partners; four attributes of a lean supply chain; supplier certification; lean implementation with legacy suppliers
- Lean enterprise principles:** stakeholders; core, extended and lean enterprises; lifecycle and enabling infrastructure processes
- Quality principles:/Six Sigma:** product & process quality; 7 quality tools; SPC; impact of quality on flow; control charts; Cp & Cpk; DMAIC; process capability
- Role of people and organizations:** employee satisfaction; relational coordination; 3 elements of collaboration; teams and IPTs
- Lean Implementation:** Kaizen/RPIW; PDSA; A3 thinking/chart

TOTAL

AVERAGE = TOTAL / 12

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