Active Learning Strategies for Teaching Lean Thinking

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Abstract

Active learning is a method of designing instruction so that classroom students are actively involved in learning concepts and content. Instead of casting students into the role of passive listener, active learning techniques strive to engage learners in reading, writing, discussing and doing things to connect the learners to the material. The Lean Aerospace Initiative sponsored the development of a foundational LAI Lean Academy® course about lean concepts. The class is targeted for an audience with little or no experience in lean concepts and it was designed with a learner-centered focus using active learning techniques. Several strategies used successfully in this class will be described in this paper, specifically: plant tours, the supply chain puzzle, mechanical assembly for lean engineering and interviews/out briefs. Results from student feedback indicate that class participants enjoy the active learning segments of the class much better than modules that are mostly lecture-based.

Keywords: Lean education, Active learning, LAI Lean Academy

Introduction

This paper will provide an overview of active learning and how it can be used throughout classroom curriculum focused on lean principles. Examples will be provided from the Lean Aerospace Initiative Lean Academy course, developed collaboratively by faculty and industry practitioners from across the country. The 2006 version of the course had 25 modules with an average of 50% time devoted to active learning. This paper focuses on four techniques employed in this class: a supply chain puzzle; mechanical assembly for lean engineering principles; plant tours; interviews and presentations. A companion paper [1] addresses the major actively learning exercise, a day long Lego simulation of a manufacturing plant. Although we don't have data which shows that active learning exercises enhance learning, our student feedback comments strongly support that active learning significantly improves student engagement with the course.

Active Learning

The term "active learning" describes a strategy for teaching where students are active and involved in the learning process [2]. Active learning places students in a participatory role, rather than sitting for a lecture. In an active learning environment, students will work with the content in a new way, make connections between new content and old theories or reflect upon the material with others (or alone). Students need to do more than just listen to lectures in order to really learn content. As Chickering [3] explains "Learning is not a spectator sport." With that in mind, it is critical that lessons be designed to involve the learners. The students must read, write, discuss or actively connect with the content in some way. Psychologist Jerome Bruner [4] supported this concept when he reported that classroom students who are actively engaged with the topic are more likely to recall that information later. Involved students are better able to use or apply information in new ways. Encouraging students to work collaboratively will help them to discover personal meaning in the concepts.

In today's digital age, people are becoming quite proficient in multi-tasking with computers, cell phones, iPods and more. Designing lessons that keep participants active, involved and engaged isn't always easy, but it's important if we want the students to really learn [5]. In an active learning environment, students will be doing something. Young children will play to learn; older students might discuss and share ideas, or apply concepts. In designing an active learning environment, it is important to think about how the exercises will reinforce the material covered, rather than just what material to cover. There are many ways to get students to think about or interact with the concepts being taught. Including simple active learning techniques can enhance any lecture. Here are some ideas to engage students in learning:

- Learners write down a short summary of what they learned
- Guided note taking - students complete a form or fill-in missing information
- Learners participate in a team exercise
- Students read and share ideas with others
- Participants discuss their experiences
- Students choose a project

The authors and their many colleagues have drawn upon the active learning body of knowledge to design and implement a curriculum for teaching the fundamentals of Lean Thinking, a topic that underpins current organizational productivity improvement [6], [7].

LAI Lean Academy® Class

The Lean Aerospace Initiative[1], based at MIT, is a consortium of government and industry organizations committed to transforming the aerospace industry through continuous improvement research and activities. LAI sponsored the development of curriculum with the specific intent of encouraging campus faculty to incorporate lean concepts into their own

[1] http://lean.mit.edu/

courses. An education network (EdNet[2]) was organized as part of LAI in order to accomplish this mission. Comprised of about 30 universities and LAI member practitioners, the group collaborated to design materials and modules into a class called the LAI Lean Academy® course. The course has been offered to audiences on campus, in LAI industry and government organizations, to faculty, and in open enrollment venues. It has served as an important way for EdNet faculty to incorporate lean concepts into their on-campus coursework [8].

The LAI Lean Academy course provides a student-centered approach to introducing lean and six sigma fundamentals. A “lean” enterprise is one that eliminates waste and optimizes the value delivered to all of its stakeholders. The course is targeted toward an audience with little or no experience in lean concepts. It has been successfully offered to a wide spectrum of audiences including: undergraduate and graduate engineering students; MBA students; coops and interns; new employees; long term employees; military personnel. Participants in the LAI Lean Academy course learn basic lean principles and experience lean practice through a variety of active learning techniques such as team exercises, simulations, case studies, interviews with lean experts and class presentations.   In addition to reading, discussions, summaries and Q&A throughout the modules, the course uses the following specific strategies to engage students:

Active Learning in Teams
- Dice game: Impact of process variability
- Mechanical assembly of sailing tools: Engineering design for manufacturing and assembly
- Supply chain puzzle: Discovery and comparison of traditional to lean supply chain management
- Day long Lego simulation: Benefit of balancing work load and design improvements
- Drawing a process map and value stream map
- Paper clip exercise: Process capability analysis

Active Learning through Personal Reflection/Experience
- Numbers game: Benefits of order and organization
- Class voting: Think about and respond to questions
- One minute summaries: Reflect on materials to pull out one key learning point
- F Exercise: Problems with visual inspection for quality control
- People exercise: Personal priorities differ from other people you work with on teams
- M&M pareto chart: Individual construction of a quality measurement tool

Active Learning for Analysis & Synthesis
- Case study: Problem solving and future state value stream mapping
- Plant tours & checklist: Evaluation of lean operation
- Preparing an A3 sheet: Practice in project management and implementation
- Interviews and Presentation: Overall synthesis of theory and practice

[2] http://lean.mit.edu/ednet

Details about four of these active learning techniques will be described in this paper.

Student Proficiency and Feedback.

No attempt has been made to measure the enhancement of student learning due to active learning; either specific exercises or in toto. However, two sets of data are obtained for each course and will be referred to later in the paper.

A self-assessment tool called VALUE is used to measure student proficiency before and after taking the course. VALUE asks for students to rank their proficiency using a six level scale for twelve Lean Enterprise Knowledge areas, such as: Definition of Lean, Process Concepts, and Lean Engineering Principles. The six level proficiency scale was taken from the MIT CDIO Syllabus [9] and augmented with a Level 0.

Level 0 To have no exposure or knowledge of
Level 1 To have experienced or been exposed to
Level 2 To be able to participate and contribute to
Level 3 To be able to understand and explain
Level 4 To be skilled in the practice or implementation of
Level 5 To be able to lead or innovate in

The course objectives are to graduate students with Level 3 proficiency, assuming they start with Level 0.

Student feedback on each module and the overall course is collected daily. The module feedback uses a five point scale (-2 to +2) where the top level is the module "provided positive reinforcement of the concepts." Open ended questions ask about the effectiveness of lectures, active learning and other course elements.

Four Active Learning Exercises

Plant Tours

"I would have liked to already know some of the vocabulary and such of Lean before the plant tour so I would know what to look for."

and

"You should have had the last set of slides earlier in the day, at least before the plant tour, as many of the concepts were discussed during the tour."

Plant tours have been used in the LAI Lean Academy course to take the place of laboratory experiences in traditional engineering course. They provide an opportunity for students to view lean concepts in action by visiting actual operations that use lean principles. With this mental paradigm in mind, two plant tours have been used to address different learning objectives.

The first tour is scheduled early in the course and has goals such as hearing and learning new terms, seeing new or unique tools being applied, and identifying enablers or barriers to implementing lean. According to Bloom's taxonomy [10], the educational objective of the tour is at the knowledge level, as a prelude to addressing the comprehension level in the first day classroom instruction. During the tours, students carry a checklist and a series of questions to consider and a place to take notes. This helps to keep the students active during the tour. Following the tour, small discussion groups share their findings from the tour in response to specific questions posed at the start of the tour. A class level discussion completes the segment, ideally involving the tour leader to answer questions or provide enriching anecdotes.

Toward the end of the course, class participants have the opportunity to visit a second lean operation. The educational objective is quite different, one of evaluation on the Bloom scale – the highest level of learning. Seeing the operation at the end of the class solidifies the concepts that were introduced during the week. Students are able to ask relevant questions, assess the level of lean implementation and evaluate the lean progress of the specific operation. Students are again given a checklist and note sheet for the tour, and the event is concluded with a discussion session with the tour leader. With proper planning, the tour leader will ask the class for an assessment of how well the plant is progressing on its lean journey. One tour leader used the opportunity for an "audit" from an independent body. On another tour, students each contributed a one sentence critique on a 3x5 card during the return trip bus ride, and these were compiled and sent to the tour leader.

For both tours, it is important to assure that the tour leader knows the incoming state of the students as well as the educational objectives and expectations. And this becomes even more important when there are multiple tour guides, which is usually the case for a class size of 30 students. The best tours have included the lead instructor meeting with the tour guide(s) well ahead of the course to align expectations. Unfortunate experiences have included students getting a "canned tour" meant for a different audience or in one case a complete breakdown in the tour guide availability. Other "challenges" have included too much noise for the students to hear the guide (microphones are strongly recommended), too large a group to hear or see things, delays due to visitor sign in protocols, and a bus breakdown. However, even under these circumstances, students have reported that the tours add considerable value to the learning.

Supply Chain Puzzle

"More activities during the Supply Chain lecture"

One of the most difficult modules for devising a 15 minute active learning exercise was the one on Lean Supply Chain Management. The answer turned out to be a supply chain puzzle aimed at the comprehension level of Bloom's taxonomy. The strategy was to let the students "discover" the basic principles of lean supply chains by solving a puzzle in small teams. This exercise uses 2 puzzles, mixed together in one envelope (See the Appendix). The class is broken into teams and asked to put both puzzles together by reading each puzzle piece and selecting which of the two puzzles the piece belongs. The puzzles, if put together properly will show the attributes of 1) a traditional supply chain and 2) a lean supply chain. Once the 2 puzzles are together, they evaluate their puzzles and rearrange if necessary. Even students who are new to the concept of an enterprise supply chain will be able to take part in figuring out the puzzles. In fact, even if the students are guessing, they are reading, making educated decisions and discussing the topic, and thereby learning the principles. If teams disagree, then it makes the students even more alert when it's time to reveal the solutions. Key active learning strategies are:

- Students must read each puzzle piece
- Students discuss the concept with each other
- The team makes a decision to assign each piece to puzzle 1 or 2
- The team reveals their findings to a facilitated class discussion.

After the teams have their 2 puzzles, they are anxious to hear if they are right! They listen actively and ask questions if they made an incorrect choice. This has been a great way for us to introduce a topic and discuss it.

Design for Manufacturing & Assembly (DFMA) Exercise

"Excellent exercises today – they made a visible connection to the lecture"

Another very challenging topic was t o devise a meaningful 20 min active learning exercise in the area of engineering practices that contribute to a lean enterprise. The instructors eventually settled on a simple mechanical assembly that supported Design for Manufacturing and Assembly (DFMA) principles. With the lead instructor preparing for a sailing trip, the choice was for alternative for attaching rigging to a clevis, as show in Figure 1. The strategy was a hands-on experience to deepen material just covered in lecture.

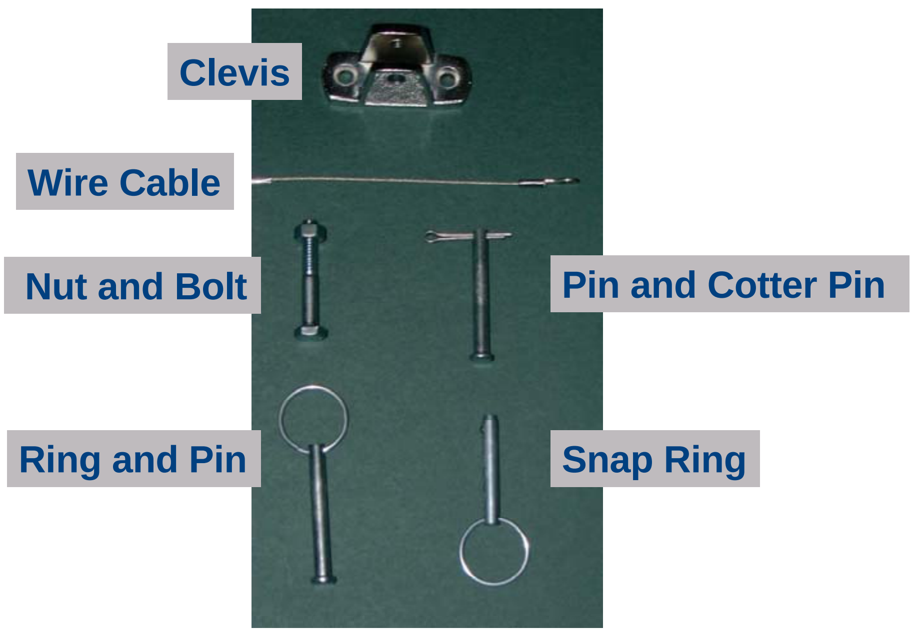

Figure 1 – Mechanical Assembly for Sailboat Rigging

Designed originally by Allen Haggerty (VP/GM Engineering, Boeing Military Aircraft and Missile Systems - retired) to explore assembly time for the four couplers, the true richness of this exercise emerged during the testing period. By actually testing the different designs of four alternative sailing tools, class participants experience the revelation that the design of this assembly really makes a difference to the end users. The number of parts, handling, assembly, use of extra tools and failure modes all affect the impact engineering design has on manufacturing and end users.

The four different sets of e fastener assemblies are packed with the cable and clevis into small baggies. The class is sitting at tables in teams of 4-6 for this exercise. Each team works on "securing the rigging" or assembling the fastener one at a time. The team observes and keeps time as one student begins to assemble the fastener. Then, as a team, they discuss the strengths and weaknesses of each design. They also complete a worksheet to help guide their conversation. So, at the end of the exercise, the students have experienced the assembly and analysis of four different designs. The faculty member summarizes by bringing out the key lessons through a discussion using the following questions as a guide.

1. Which fastener design had the shortest time for assembly?
2. Which design had the fewest parts to assemble?
3. Which design probably needed a tool to properly assemble?
4. Were there "parts handling" issues with any designs?
5. Which design might degrade with wear and tear?

Interviews and Outbriefs

"The interviews and presentations proved to be most valuable"

An active learning strategy was selected as the culminating course experience to assess student learning and instill student confidence in the use of their new knowledge. The approach was to have students interview an expert and summarize their findings in front of their peers, instructors and sponsors. This exercise was aimed at the highest levels of Bloom's taxonomy – Synthesis and Evaluation [10].

Toward the end of the LAI Lean Academy® class, participants are assigned to teams of three (or at most 5) for this exercise. Each team is given the opportunity to speak with a lean experts/practitioner about the projects that he or she has led. Students are asked to develop a set of questions for the interview, conduct the one hour interview as a group, and then synthesize their findings into a 5 minute group oral report. The students are expected to compare interview findings with course material. This technique provides an opportunity for students to engage in dialogue with an expert which can be a very powerful experience to use their newly gained knowledge. This activity moves the theory of the course content into reality with examples of how a lean project manager has used the tools and ideas presented. This exercise enables each team to synthesize the best learning points to share with other class members, reinforcing the key learning objectives of the class.

Success and Student Feedback

Results from student feedback indicate that class participants enjoy the active learning segments of the class much better than modules that are mostly lecture-based. Daily feedback sheets collect data on every module that is offered. Through the VALUE score sheet given prior to class as well as after the class, it is clear that the class participants have increased their proficiency. Figure 2 shows the increase in student VALUE scores for 2005 course offerings. These results show that immediately following the class, students perceive that they have a much better grasp of lean concepts, tools and applications.

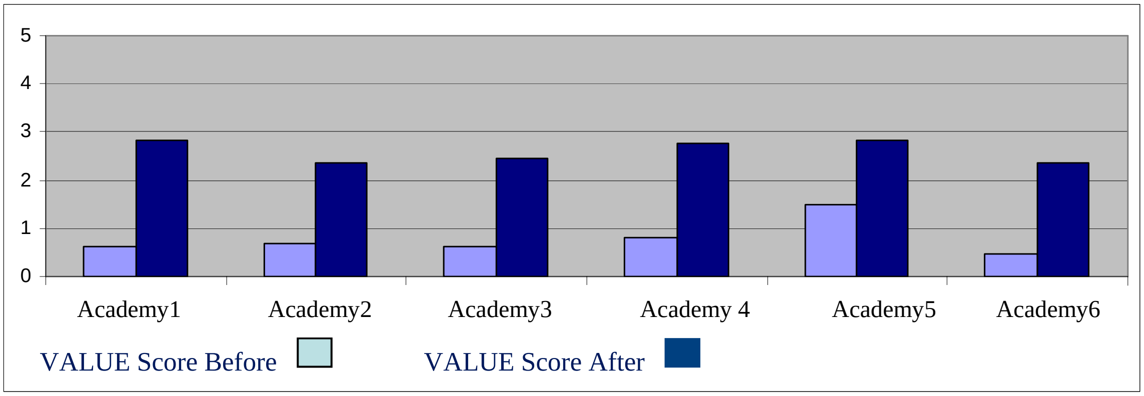

Figure 2: Before/After Student Proficiency (2005 Classes)

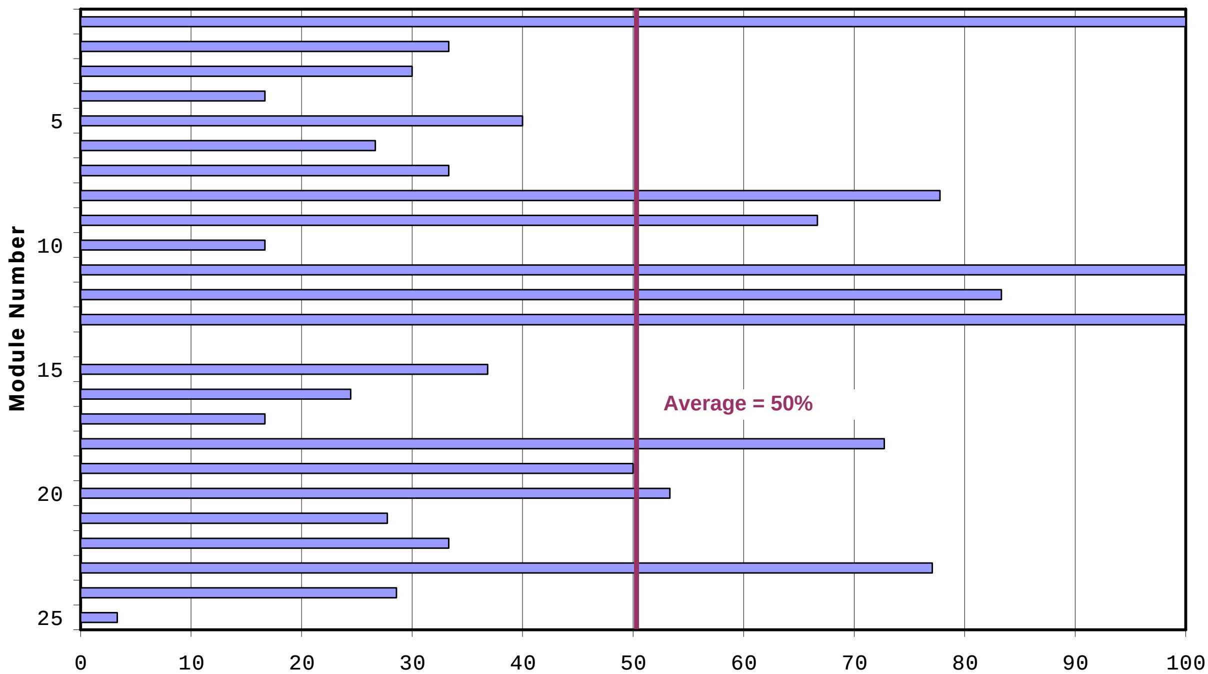

Figure 3: Percent of active learning included in each module

At the end of each day, the student comments give constructive feedback and suggestions for improvement. Often, students are positive about learning the basic principles of lean thinking. This paper focuses on active learning strategies throughout our class and Figure 3 shows the percentage of active learning incorporated into each module. Even though we strive for a good balance of lecture and activity, we still receive suggestions and requests for more hands-on learning! Examples from last year's classes include

"More hands on practice of the value stream mapping"
"Some modules seemed long and could have been more interactive,"
"The simulation was terrific. Suffering through mistakes helped the learning process"
"Make presentations more interactive."

These comments and results show that the class participants appreciate the use of active learning in the classroom. It is also important to include active learning so that students have the highest level of learning and recall. Incorporating exercises and activities will help students to solidify their understanding of topics. When the participants are engaged with the material, their ability to recall the material is increased [4].

Connections to CDIO and Engineering Curriculum

The LAI Lean Academy® course benefited from many of the CDIO approaches, including a focus on the use of self-assessment, detailed learning objectives, and active learning techniques. The course was created (and continues to be improved) by faculty and industry professionals from across the country. The CDIO imitative helped to make the LAI Lean Academy class robust and successful in several different environments and for a variety of audiences. Over time, the curriculum has been updated and each year new ideas are added that will keep learners engaged in the materials.

It is particularly important to bring active techniques into engineering education. The four exercises described in this paper can be transferred into engineering classes. For example, taking engineering students on a tour could enhance their understanding the interactions between engineering and manufacturing or operations. This might also be done using video. The key active technique is to set up a checklist for engineering students before the tour or video. This will establish expectations about what to notice, and set the stage for discussion once the tour is over. Working with the tour guide ahead of time is essential.

The puzzles exercise can be reworked into any curriculum including engineering education. Simply take characteristics that support your concept/topic and group them into one puzzle, while putting terms that are opposites into the other puzzle. The key is to get students to read and discuss the characteristics and classify them as part of one group or the other.

The example of using a mechanical assembly such as sailing rigging is an innovative way to show a concept such as Design for Manufacturing & Assembly. This exercise is appropriate in an engineering classroom, but can be applied in other places too. The key to this technique is to use a simple common hobby or household item to demonstrate the concept from a new perspective. Encouraging students to actually work with something tangible (instead of simply telling about an example) involves them in working with the material and stimulates thinking in new ways..

The final example of interviews and presentations is an excellent technique that can be moved into engineering education. One idea is to request that students interview an engineer on their own time. Alternatively, one class session could be set aside for bringing in guest practitioners for students to interview. Engineering students will interact with the experts, discussing class concepts and how they are being applied back on the job. This can be done in teams, and the students can present what they have learned to each other.

Conclusions

Active learning is an instructional strategy that enables students to be active and fully involved in understanding new concepts. The LAI Lean Academy is a course developed through the collaboration of industry members and professors from several universities, to teach students about the fundamentals of lean principles. This class was specifically designed to be learner-centered, incorporating a variety of active learning techniques. Use of active learning techniques in the LAI Lean Academy classroom has had an impact upon the success of the academy class and has helped encourage student involvement in their own learning. Students are engaged and interactive with faculty and facilitators throughout the course. Student feedback shows that the participants prefer modules where active learning techniques are included, and they even ask for more. Several techniques inspired by the CDIO initiative such as self-assessment, detailed learning objectives and active learning have been essential components in creating this highly successful and robust educational curriculum. The ideas and exercises used here can be easily transferred into many types of academic curriculum, including technical topics. Examples have been suggested for moving these activities into engineering education, and the authors encourage this application of the materials presented.

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Biographical Information

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Appendix
The appendix on the next page contains an example of the *Supply Chain Puzzle* game, described in this paper.

Appendix

Supply Chain Puzzle