2006-1879: LEAN EDUCATION - HAS ITS TIME ARRIVED?

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Lean education – has its time arrived?

Abstract

The curriculum for almost any university-level technology program is overloaded. The commitment to keep up to date with industry developments and at the same time cover all the necessary principles of science and engineering means that more and more is being inserted and little is ever taken out. As a response, the paper considers the application of lean manufacturing techniques to education. The metrics to be developed and optimized are extendability, cycle time and reduction of waste. A preliminary analysis of selected courses has been undertaken and implications of the outcomes are discussed.

Rationale for change

This paper outlines a response to a number of hot-button technology education issues. What constitutes Technology and how it all links to an appropriate program of study has been debated for years in every university. It is particularly difficult for the case of electronics where the industry operates on a global scale using more dense chips, sophisticated design tools and a production process that challenges the limits of understanding in many areas of science, engineering and math.

Academic programs strive to give graduates the skills to contribute quickly when they join the industry ranks. However, programs must also provide a good grounding in the basic science and engineering principles and techniques that underpin all applications. The usual solution is to add new material to senior courses and compress the existing topics into the earlier stages of the curriculum. More is added every year but nothing can be removed because it is relevant to the whole corpus of subject knowledge. In addition to these content issues, there are the inevitable administrative fellow-travelers of confusing pre-requisites and enrollment rules. The usual outcome of this process is a program of study that satisfies none of the stakeholders.

There is nothing new in this observation. In the mid 90s, the National Science Foundation sponsored a major analysis of curricula[1] that led to some important collaborative programs. However, it was also recognized that it was difficult to absorb these initiatives into the mainstream of technical education[2]. In spite of these and many similar endeavors, the issues remain and the concern has moved to even higher levels of strategy and international competitiveness[3]. Undoubtedly, we can no longer take our pre-eminent place in the high-tech world for granted and one component of any solution will certainly be a restructured and enhanced education process.

Leadership by the National Academy of Engineering, the IEEE and industry associations is vital to create the climate for change but the job still has to be done in every department by faculty who share the vision. For the case that forms the basis of this paper, the catalyst for change was a productive ABET review in fall 2004. The process to establish and then execute continuous improvement naturally prompts the question of how it should be done.   Processes such as ISO9000 or QS9000 do not exist in isolation in a company; they are part of a coherent culture to organize the business so that quality products and operations can be delivered.   It therefore seemed logical that we should examine the academic process for curriculum development to see if it could be more readily organized into a format for continuous improvement. To add purpose and direction to our commitment, we started a dialog with our industry advisory board to develop a balanced scorecard for the department. From that activity, grew a prioritized strategy map and some ambitious goals that clearly needed a new approach.

As we contemplate change, it is useful to compile a list of endemic issues that could benefit from a different approach to the organization of the program:

- Degrees are taking longer to complete. Even full-time undergraduate students need at least 5 years to graduate.
- Tuition fees are rising much faster than inflation.
- Since many students have jobs, they wish to schedule their own time to learn rather than have to conform to a fixed and inconvenient class schedule.
- The 'essential course content' keeps increasing.
- The feedback from graduates in the workplace is that there is a big gulf between the skills they need to prosper in a company and what they spent most time learning at school.
- Increasing bureaucracy and the pursuit of external funding leaves little time for faculty to meet their own teaching standards.

To a manufacturing engineer, these are all familiar characteristics of a 'push' system. The production engine, in this case the academic program of study, is a self-defined entity with an internally-focused goal to crank out more of what it is able to do.   As a result, the production process is decoupled from the eventual application but sees nothing wrong in that. If challenged, the response is that all the content is relevant; it is knowledge that is used somewhere and all students get good jobs. Thus, if the engine works well, there is no need for change. Responses like that were often heard 30 years ago when the US manufacturing companies were faced with Japanese competition. Unfortunately, they are responses based on flawed criteria for excellence. We should be more concerned about the efficiency of the educational engine and where it is going, not where it has come from and how much baggage it can carry.   The outcomes focus of the ABET process should be a sharp wake-up call that there may be other ways to deliver the educational solution.

Features of lean operations

Lean manufacturing was introduced to eliminate the clear inefficiencies of 'push' processes. The impact was economically dramatic and came as an unpleasant shock to the automotive and electronics industries in the 1970s. It was sometimes called 'just in time' or 'agile' production and for this purposes of this paper, all these techniques are fundamentally similar and based on just three simple priorities:

1. Only build what the customer needs when they ask for it.
2. Eliminate all non-value-added steps in the process.
3. Quantify the goals, actions and outcomes and make them very visible to everyone.

To execute these activities, many changes in operational business procedures had to be put in place. Waiting for a customer order is clearly a risk and could result in long delays if the response had to start from scratch. As a result, a much clearer combination of pre-qualified building blocks was put in place. They could then be assembled and configured (often with software) promptly as needed. To provide a quality product, the whole system of statistical control was developed through processes such as Six Sigma to quantify the capability at every stage. With such an intrinsically modular structure, it was logical for specialist groups to spin off as separate business units but all continue function together as a responsive supply chain. Companies found that by focusing on their core competencies, proven quality operations and transparent interfaces, the modular approach could be structured to deliver a rapid and well-targeted response.

After a generation of lean operations in manufacturing industry, three types of practitioner are emerging as represented in figure 1. They share a strong core of common communication, data management and business process skills but the response to increasing systems complexity is to foster workforce development in three complementary roles: specialists, integrators and sustainers.

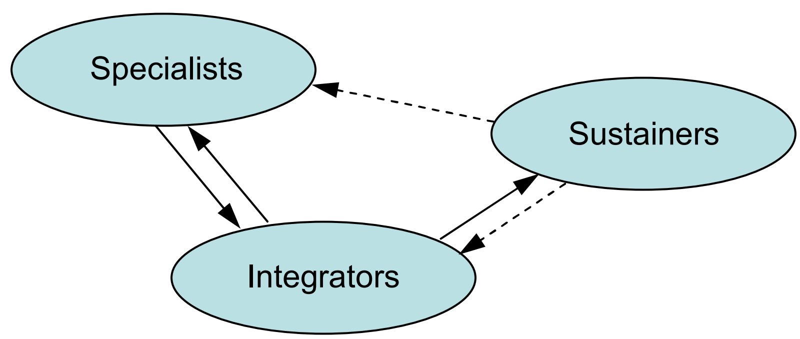

Figure 1. Roles within a lean operation

- Specialists are the practitioners who know how the detailed components of a system may be designed, produced and optimized.
- Integrators are the master planners who can fit the components together to determine the functionality of an overall complex system.
- Sustainers are the system operators who keep the complex systems operating and updated to support the overall mission.

One of the purposes of this paper is to consider how technology education can provide the skills needed for the participants in figure 1. Lean manufacturing led to the creation of new roles so it seems logical to use a lean education structure to prepare the next generation to fill these roles. Since a system may have a life that is measured in decades, the three functionaries take the lead at different times in the life-cycle to provide a competitive long-term solution. The communication arrows between the groups show their interactions. The integrator has a pivotal role and an obviously strong interaction with the specialists. However, the direct feedback from the sustainers to the other groups is a lot weaker than it should be in a truly responsive system. An interesting observation is that when the IEEE Spectrum identified "ten great jobs" for 2005[4], one common feature was the extent to which they focused on the integrator-sustainer interface. Perhaps this is a pointer to the in-demand jobs of the next decade.

Methodology to apply lean operations to the education process

Libraries are well-stocked with books on lean manufacturing[5]. However, to apply the concept to education, we need to develop analogs. If we say that the purpose of the degree program is to extend the student's capability to work in a professional engineering role, then we have a basis to define many associated lean terms such as waste, cycle time and extendability. Each of these terms in turn has many component factors which need to be examined separately to set up a lean process.

It should be emphasized at this stage that lean education is **NOT** "education-lite". To continue the comparison with manufacturing, a lean process is an essential qualification for world-class performance and we see no reason why education should be different. Examples of the detailed analysis will be considered in later sections of this paper.

The single feature that gives lean processes their competitive edge is that they require a balanced view of the whole process. Thus, everyone involved should be as aware of the strategic picture as the detail they work on personally. As a result, many small activities can be run in parallel and still contribute to the overall system improvement. There are three aspects to implementation of any lean process:

a. Initial conditions. The work is carried out by teams made up from all the stakeholders. They have to share the vision of a better outcome for each of them. By starting with a broad-based team, the most obvious pitfalls are identified early and the nucleus of a sustaining group is also created. Experience suggests it is best to start with small projects and let success drive the pace. With metrics and data to prove the outcomes, moving to a larger scale is not hard to sell if all the participants think it will make their lives better.

   The other set-up component is a clear list of desired outcomes. In our case, this is a combination of the ABET outcomes, a list of about 30 personal, business and technical skills and a list of technology trends that the future workforce will have to accommodate.

b. Mapping activity. The first step is to describe exactly what is done within the designated process. In our case, the basic unit is a single academic course. It takes a little discipline (and probably an experienced facilitator) to record everything that is done – not what we think is done or how we would like to improve it. The next stage is to measure which sections of the course content deliver desired outcomes. If there is no link, the activity can be eliminated or transferred to another course.

c. The final stage is to institutionalize the two steps above as a 'pull' system. That means looking at the whole program to decide if the aggregate contribution to the outcomes is still balanced. For example, it may be enough to treat a topic such as linear circuit design only once but topics that relate to ethics or reliability might be better covered by many small examples throughout the program. The steady lean state is reached when the mapping, analysis and change become routine maintenance tasks. This does not mean that we have the best lean system possible. It is only a local optimization.

At this point, it is worth asking how the process differs from that used for ABET documentation. The simplest answer is that the lean process is the next step. While the ABET (or any ISO-9000) process demonstrates conformance to realize continuous improvement towards generalized goals, a lean process attempts to find more efficient ways of working. In a nutshell, the ABET process is good for the customer; a lean process is also good for the provider.

Trial implementation

If processes such as continuous improvement or lean operations are considered vital within our target industries, it seems logical that we should describe them and demonstrate their use somewhere in the curriculum. In our case, the topics are largely concentrated within one course on business processes. It traces the stages in a product life cycle as well as the associated quality and reliability procedures.

As a series of class exercises, we applied the lean analysis to the content and activities of the degree program. To keep the work within bounds, the metrics were limited to waste, cycle time and extendability. In manufacturing analysis, there is a hallowed tradition that classifies waste into 7 categories following the pioneer work done by Ohno for Toyota[6]. The students responded enthusiastically to identify the 7 wastes in their own educational experience. Their main points of agreement were:

#	Waste	Example
1	Over-production	Studying techniques that are obsolete or never used
2	Waiting	Poor class scheduling or waiting to have forms signed
3	Transport	A 1 hour drive to campus for a 1 hour class
4	Over-processing	Performance determined by time spent rather than competency
5	Inventory	Acquiring skills that are not aligned to future job requirements
6	Motion (intellectual)	Un-necessary pre-requisites or repeated topics
7	Defective product	An A student who can only do an average job in a company

Many of the examples overlap but there was a strong consensus on these points even though the class was very diverse (full-time students, full-time employed, unemployed, international, etc.) From an operational viewpoint, the useful thing about this activity was that the comments could be scathing without being personal. That was a useful demonstration.

In the interests of balance, it is appropriate to list the wastes that a typical faculty member might experience.

#	Waste	Example
1	Over-production	Repeating information for students who miss a class
2	Waiting	For students who miss appointments or arrive late
3	Transport	Attending meetings where every department is represented
4	Over-processing	Covering the same points repeatedly in academic meetings
5	Inventory	Teaching topics that have long been obsolete
6	Motion (intellectual)	Repeating explanations that should have been absorbed earlier
7	Defective product	Students who have no commitment to education

The potential to improve cycle time evolved from many of the wastes. A shift wherever practical to web-based learning has the capability to reduce some of the wastes associated with transportation, waiting, over-processing and motion. Once the obvious wastes have been eliminated, there remains the question of how to achieve the desired outcome or competency level more efficiently. That requires clear definitions and objective measures for the different features of cycle time, eg: the time to learn how to use a tool or, (on a large scale) how long a degree program should be. In almost every case the analysis led to some version of self-paced learning with class sessions to clear common bottlenecks or to integrate several small parallel projects. This sort of learning environment has clear links to distance learning. Unfortunately, it also needs the same substantial time commitment for solutions that are still developing slowly.

Extendability proved to be the most challenging measure. It is inherent in the first attribute of lean processes – to produce product only when required. The conventional manufacturing solution is to have pre-qualified modules that can be quickly assembled. They can also be upgraded separately and still be designed to work together – although the software world demonstrates that such a solution does not come painlessly.

The educational equivalent is to distinguish between basic concepts and practical examples. A statement to that effect probably exists in the Forward to every program of study. However, the list of wastes clearly indicated that in spite of good intent, the process doesn't work very effectively. As we look ahead at future trends in electronics technology, the problem becomes more difficult as systems become larger, more complex and electronics continues its trend as the enabler for almost all technical solutions. Fortunately, the lean implementation process provides a way forward. The systematic mapping of activities and their dependencies is exactly what is needed to create an educational experience that is intrinsically extendable. The benefits are likely to be significant to all stakeholders if the process leads to:

- Guidelines to select course combinations to provide the best flexibility and personal skills to meet future career needs.

- How to structure a program of study that is compatible with the trends in global supply and consumption of electronic products and systems.
- A credible expectation of return on investment in education through enhanced or more secure lifetime earnings expectations.
- More efficient paths to the levels of competency that will be expected from future technology professionals.

This work is the basis of several projects that will be reported at a later date. A more speculative question is whether the adoption of lean education principles will have the same effect as in the manufacturing sector where standard products are now assembled from globally distributed sources and delivered back to a global market. At present, higher education is largely locally prepared for a local market and the preparer is firmly in charge. The widely touted changes that would follow from web-supported education have not substantially changed the system of control. Perhaps from that experience, we can infer that the message is more important than the medium. A lean process would let the user determine the message and that might be a trigger for more widespread academic organizational change.

Conclusions

The process to create an educational structure that can qualify as 'lean' has been examined for a single technology degree program. It worked well to identify the major wastes and how they might be reduced. The methodology to reduce the cycle time to achieve competency in clearly bounded skills has also been mapped out and some of the non-value added steps eliminated. Extendability is a more challenging attribute that is the focus of a follow-up project.

A lean education process can be looked on as the next stage beyond the outcomes-focused process that has been implemented to meet the new ABET criteria. With extended goals to represent the skills needs of future technologists, courses can be constructed to have the features of a 'pull' system that characterizes a lean process.

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