Developing Engineering Curriculum: The Lean Way

Sunny Nanade, Sachin Lal

Abstract: Educational quality is winding up progressively vital for the individuals who are associated with it either specifically or indirectly, and for the individuals who utilize its administrations. Education institutes around the nation—truth be told, far and wide—are reproducing their work forms, frameworks of human communication, statements of purpose, and their long-haul vision and techniques, all with the devices and reasoning of Quality Management. Still many institutes are thinking that it's hard to adjust the educational modules with adjusting innovations. This paper investigates how Lean added more educational value to education and tries to find the use of same for developing engineering curriculum.

Keywords: Lean Education, Engineering Curriculum

I. INTRODUCTION

The time has come for those born in this millennium to enroll in universities and it is necessary to rethink and redefine the way education system should be changed. The curriculum and the system followed by the institutes are being reconstructed to various questions to alter the educational system. The older system focused on what is taught rather than to whom it was taught, or the method of teaching and this system is getting outdated. Due to the rise of the technological advancement, the learning style is being altered by the students to internet-based learning since the last decade. This has created problems since the educational institutes haven't kept up with the changing technology. Smart students who are good with technology have already come up with new ways to learn through the internet making their curriculum not effective enough for them [1]. The students have connection with the other learners for collaborative learning and hence can teach each other the concepts they don't understand. The educators have to understand the upcoming technology and have to be more familiar with them in order to make improvements in the teaching methodology. When more innovation is made in the curriculum, the students will have more scope to solve problems and it will become interactive. These new methodologies will be able to keep up with the learners and will change and develop as quickly as them [2]. Lean Education is the implementation of Lean principles in the field of education. Lean principle is the practice of improving something continuously. The principles have to be followed in the educational system by continuously adapting the curriculum to the changing world. This adaptation in the syllabus, infrastructure and methodology is very difficult to the schools and universities. Usually, the curriculum is changed every four years,

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Various innovations take place during this time period making the syllabus absolute and outdated. However, if the educators add the new technology immediately when it is still in the development stage, there are chances for the technology to fail and it is a waste of time to learn it leading to failure in the system. Hence, the educators have to be dynamic and quick learning and they have to adapt with the ever-changing technology to frame the right curriculum. However, the learning phase of the educator must be a step ahead of the learners or it will lead to a waste of resources [3].

The wastage will lead to the following:

The institute will not be able to give a world class education.

The educators cannot contain the students in the current curriculum.

The educator will not be able to deliver the necessary learning objectives. The objective cannot be achieved as desired.

Hence it can be said that when new technologies that are still in the incubating phase is implemented into the system, it will lead to an educational waste. To reduce this educational waste and to increase the educational value, better management and better educators who can adapt at the right pace are required to achieve the objectives. Lean Aerospace Initiative (LAI) was created by four educators to develop a methodology to teach students who had to undergo an internship [4]. This course has been successful and has been taught to various people. Their success in achieving the objectives in such a short period of time contains the solution to avoid the educational waste and creating better outcomes. It gives hope to the educators and assurance that

the curriculum will not be wasted and can be applied more effectively.

Hence, lean is a tool which can increase the quality and reduce the educational waste and hence the various techniques can be studied to improve the educational system. The accessible simulation techniques that are open-source will be studied to enhance the curriculum and other tools that will be used for managing the admission will also be discussed in this work.

II. Review of literature

Several researchers have carried out detailed studies on Lean Education and simulation of the components. Lean has been implemented in various industries especially in the educational field and has been successful [5]. However, it has also drawn lots of criticism that the employees are being exploited [6]. It has also been criticized to a fad with no actual use in the educational field [7] and inflexible [8].

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Comparing to the actual production, a simulation has more advantages. It takes less time to model and evaluate the production process in a simulation [9]. Simulation of a factory or a company gives the students a chance to understand the problems and the burden encountered by the managers when important decisions are made. It is more effective since the user has an important role in the decision process of the simulation. In the simulation, various components used for processing can be used effectively with high accuracy. These components may be physical components like the equipment and resources used in the industry or conceptual components like plans and schedules. The creation of the actual factory is difficult due to the cost constraints and hence, simulated factories are used to denote the real plants in the manufacturing process [10].

The structure of a simulated factory has been proposed in [11] and it has been studied and evaluated by using it as a manufacturing process. Discrete event analysis has been used in a simulation by [12] and it has been used to predict the progress in the work in a factory that fabricates wafers. The process of lean management and its implementation in the educational field has been discussed in [13]. It has also explained the options of implementing it in other industries like Medical, Administration and IT field. The usage of modelling using simulation to design and optimize the manufacturing process of PCB has been demonstrated by [14]. The need to improve the modelling and the need to estimate the production data has been suggested by [15] and a simulation of a factory for educational field has also designed with better modelling parameters and production data.

Lean Education has been used across the world by various institutions. The LAI (Lean Aerospace Initiative) is a collaboration of various universities to develop and initiate a syllabus to teach the fundamentals of lean six sigma. It has been created at MIT in 2002 and the faculty have created a course with a duration of one week and has been delivered to various industries and government sectors. The course map of the topics and the techniques of assessment have been updated in the knowledge base. The methodology of this LAI and its contribution to Lean Thinking has been studied in Enhancing Faculty Competency in Lean Thinking Bodies of Knowledge[4]. The results have shown that this method has effectively increased the ability to impart the Lean Education. The skill of the instructors in 12 Lean education areas have approximately increased from 3.2 to 4.2 on the scale created by MIT to determine the proficiency. The educational network has effectively increased the method of teaching as compared to other known approaches.

A simulation that is based on the Kanban theory and a simulated game based on the lean architecture has been proposed [16]. The use of hypertext pre-processing and the usage of structured query language makes the game more interesting with tools that give knowledge. The findings have suggested that the most widely used games that are used for education do not communicate well with the users and hence innovative simulations are required with better GUI to improve the lean education. A VE Suite (Virtual Engineering) has been used to solve it in this work.

Lean Education is a nice methodology to improve the student-centered learning since the student selects the way of learning thereby improving methods of learning. This has been discussed in Lean Education for Applied Science Universities: A Proposal by Federal Institutes of Applied Sciences in Brazil [17] and the basis that has to be applied in the coming years has been studied. Hence, a project has been recommended for an institution and the following results have been concluded:

Concentration on the problems faced by the students and companies while devising a plan for the course,
Unity and uniform syllabus of students from different universities. The learning is centered on the students.
Uniformity of syllabus among different streams of education. Improvement of the students' skill and their capabilities.

The students are assessed based on their skill, not on what they have learnt from the text books
Concentration of the learning process and not on the results of their examination. Less number of instructors are sufficient for the teaching process.
Better relationship between the students, faculty and the company.

This may improve the overall educational system and get better and effective results.

The demand for engineers with a deep knowledge of the lean principles is increasing day by day in various industrial fields. The present methodology for lean education utilizes training and simulation, but the simulation games that are available in the market are complex and cannot store the results. They also cannot be modelled. Hence, a virtual simulation platform that can make the students conduct different experiments by using lean principles have been created [18]. The proposed system solves these issues by using a simulation software called VE-Suite and contains user friendly boxes, machine's graphical model, measures the performance and its layout can also be edited. Various management principles have been used in the work like Little's law, EOQ and cycle time to apply the lean concepts. Initially, a conventional production line with push type mechanism has been used and this has been improved by the students using the lean technology. Future work of this paper will be to create a supply chain where the universities will act as a vendor and a complete virtual manufacturing procedure can be simulated.

When a comprehensive algorithm has been applied to help to improve the performance of the lean implementation, there has been accomplishments like utilizing a wider technique [19]. The performance of the application of lean can also be improved by using special goals and taking movement towards these goals [20]. The scope of the lean education has been tried to be expanded to solve the problems of organizational and cultural issues. These issues have been tried to be solved [21] by using an educational project that has been funded by the NSF (National Science Foundation) by improving the technical and professional skills of the student in lean education.

There has been lots of applications of lean principles in creating value, improving efficiency and reducing costs. But the implementations that had been done has very less performance and not as expected. Lean

system has been implemented for four decades in North America and the enterprise transformation has not yet taken place as expected. The reason for this might be that lean has been used only at the operational level of the organization and not at the enterprise level. The adults who are learning have to know the reason for the learning and they should be motivated by both intrinsic and extrinsic motivators. These factors play a great role in content of learning. This is in conflict with the conventional method of learning where the method of using lean tools are more focused on. The correlation between the motivation for the adults to learn and the traditional implementation of the lean process has been explored and addressed [22].

Most companies that only had manufacturing process as the main source of income previously are now shifting to both goods and services. This is possible due to the implementation of the lean principles and is known as sterilization or PSS (Product Service Systems). Lean has also been used in the service operations, but there is no knowledge among many people, when the lean education is implemented in PSS. Hence, two companies that use lean technologies and are recognized for both products and service has been utilized to evaluate the operation of PSS in the lean environment. Multiple case studies have been proposed to propose a framework to link the lean environment with the PSS [23].

The critical success factors have been identified by implementing lean education [24]. It has been implemented in SME (small and medium enterprises) and the case studies have been taken for a period of four years. It has been observed that the actual problem in making the lean process successful was not due to the problem with the management, but it was due to the knowledge gap since they have been ignorant of the process. Hence, this works considers the knowledge factor as a key parameter to implement the lean education successfully mainly in factories that has less resources. The knowledge in management and education is necessary for the people who work in the implementation of the simulation especially in SME due to the limitation in the resources. However, this paper has concentrated only on SME, thereby neglecting the large enterprises.

There is hardly any research regarding the cultural aspects and organization philosophy in lean education. Hence, the lean implementation and its influence has been identified initially and then the aspects have been aggregated into themes [25]. The perception of the participants and the cultural position has been identified for manufacturing SMEs. The most effective lean tool has been used for addressing the need for organizational culture to simply the lean implementation and use its success in SMEs of Saudi Arabia. Since exploring culture is necessary for the topic, it is necessary to use the qualitative research. The implementation had been performed in 37 aspects from the questionnaires.

III. Results and Discussion

From the literature review on various lean educational system and the simulation process, it has been seen that the researchers have focused mainly on the organizational and the management side of the lean system. The study of lean process in the field of education is very rare and simulations have also not been done effectively.

Table 1. Result of The Experiment

Course activities / Students' graduate attributes (knowledge and skills)	Lectures	Class applications	Written assignments	Problem-based projects	CAD applications	Additive manufacturing	Progress tests	Class presentations	Feedback	Course design ranking* *(Likert scale 1-5)		
										Improved design	Initial design	Areas of improvement
Integration of knowledge	▶	●	⌗	●	●	●	●	●	●	5 3		
Problem-solving skills		●		●			⌗	▶	●	4 3 x		
Communication skills		⌗	●	●	●	⌗	⌗	●	●	5 2		
Teamwork		⌗		●	⌗	⌗		●		4 2 x		
Creativity		⌗	⌗	●				⌗		4 3 x		

● Strong relationship; ⌗ Moderate relationship; ▶ Weak relationship.

From these aspects, the objectives of the proposed research work are as follows:

1. To build lean based process for engineering curriculum development
2. To assess the educational value of the lean based developed system
3. To adopt the changes based on the assessment into the framework.

From the literature review, various gaps have been found and they have been given in the objectives as the steps for this project. In order to make the study helpful, the Model Syllabus as proposed by AICTE for Engineering will be studied. The methodology followed to implement the objectives will be given below.

As stated in the objectives, approach is based on three main phases—build, measure, learn. The data will be learnt by the system and will improve it automatically. Iterative rounds are used to learn the curriculum and thereby improve it. The training program can be configured to solve Lean tools and for different time durations. The various Lean tools that can be used are the Value Stream Mapping (VSM), Single-Minute Exchange of Die (SMED), Poka Yoke or Kanban.

The learning algorithm starts initially and after that the performance indicator of the Lean curriculum is measured using KPI (Key Performance Indicator).

This can be done in MATLAB by giving the parameters such as time taken, quality of the course, feedback of the students as an input and obtaining the parameters such as WIP (Work in Progress) as the output. Based on this KPI value, the problems will be expressed and suggestions will be given by the students for improvement.

The course will be taught with these suggested changes and with this information, better action will be taken on the curriculum. If everyone in the team approves this action, it is implemented in the curriculum. This cycle repeats and thus the curriculum can be altered dynamically.

IV. Conclusion

Use of Quality Management tools is necessary to make education sustainable. One such tool, Lean, has been very useful to many universities all over the world which opens the path to develop an adaptive system. Uniformity of curriculum with Model Syllabus can be achieved when the process is made streamlined with minimum educational waste and maximum educational value. Use of AI based Software and enabling Machine Learning from the inputs can help adapt the system and make it more acceptable to all.

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