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Teaching Lean Manufacturing in Educational Field Through LBD: A Case Study in an Engineering School

Meddaoui Anwar[1], Hachmoud Sami[2], Allali Hakim[2]

[1]Department of Industrial Engineering, Ecole Nationale Superieur d'Arts et Metiers, University Hassan II, Casablanca, Morocco

[2]Department of Information Technology, Faculty of Science and Technology, University Hassan I, Settat, Morocco

Email address:

ameddaoui@gmail.com (M. Anwar), sami.hachmoud@gmail.com (H. Sami), hakim-allali@hotmail.fr (A. Hakim)

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Abstract: Classical learning in an engineering educational environment presents problems for most of students to understand in practice some engineering methodologies, especially lean manufacturing. Lean is a philosophy initiated by Toyota to eliminate waste, organize workplace and procedures to enhance productivity. The current paper compares efficiency between classical teaching method and learning by doing pedagogic process. The purpose is to propose a new manufacturing educational model based on previous works and return of experiments. A case study is established to support proposed model by measuring training efficiency and students' creativity compared to classical educational tools. Future researches could use the proposed model in other educational fields.

Keywords: Lean Manufacturing, Learning by Doing (LBD), Efficiency of Teaching, Teaching Simulation

1. Introduction

1.1. Learning by Doing (LBD)

Recent advances in technology have positioned simulations as a powerful tool for creating more realistic, experiential learning environments and thereby helping organizations meet these emerging training challenges [1].

The result has been an increased prevalence of simulation-based training in both academia and industry. Faria, for example, found that 97.5% of business schools used simulation games in their curricula [3]. Faria and Nulsen estimated that 75% of US organizations with more than 1,000 employees were using business simulations, and it has been estimated that in 2003 the corporate simulation-based training industry was between $623 and $712 million globally [4], [5].

A number of emerging challenges, including globalization, economic pressures, the changing nature of work, and work-life issues, have combined to create a business environment that demands innovative, flexible training solutions [1]. Technological advances have served to position technology-based training applications as practical tools for addressing these challenges [5]. Technological advances have expanded both the breadth and depth of training technologies [6], and today's high-end technologies offer the capability to provide information-rich content and immerse trainees in high fidelity, dynamic simulations. This focus on technology is evident in the simulation-based training literature as many studies have focused on either describing the technological features of simulations (e.g., [5]) or on describing specific training systems and applications (e.g., [7]).

1.2. Lean and Productivity

Basing on Taylor's scientific management works Henry Ford developed the first manufacturing assembly process and gave the first step of what called now Lean Manufacturing. His first idea was the "continuous flow" for his Model T automobile. But Ford's process had many flexibility problems. Other manufacturers began to use Ford's ideas, but many realized that the inflexibility of his system was a problem. Taiichi Ohno as a technical manager was developed the Toyota Production System (TPS), which used just in time manufacturing methods to increase efficiency.

Lean production term was introduced the first time in the book titled The Machine that Changed the World: The Story of Lean Production [8]. As he reported, Toyota used successfully its processes and, as a result, it became the most profitable manufacturing company in the world. Lean approach is based on finding efficiencies and removing wasteful steps that don't add value to the end product. There's no need to reduce quality with lean manufacturing – the cuts are a result of finding better, more efficient ways of accomplishing the same tasks.

To find the efficiencies, lean manufacturing adopts continuous improvement tools, as "single minute exchange of die" and "Total Productive Maintenance" to enhance productivity and satisfy customer's quality, delay and cost.

1.3. Challenges of Lean in Educational Field

Lean management and organizational learning have been two driving forces for today's business' success by contributing to competitive advantage in organizations [14]. Between industrialist's recruitment needs in terms of school candidates and university subject's requirements, both professors and students find difficulties in the teaching process. Professors find it difficult to meet university requirements and industrialists with the classical learning system, in particular, courses and tutorials. As for students, principal difficulties are about correlation between integration in professional field and learning problems. For Emiliani [9], leaders' unwillingness to engage faculty in Lean management is unfortunate because academic) work is the core value-creating activity in HE institutions. Administrators can be perfect in their Lean efforts in administrative processes and achieve perfect outcomes, yet the institution will still suffer because processes in the academic unit remain unchanged. It does not understand its processes in detail nor does it understand how to improve them, with the wholesome goal of making things better for both faculty and students, and staff were academic and administrative processes intersect.

Some leaders of HE institutions are seeking an educated response to basic cost, quality, and service delivery problems. They have adopted Lean management to improve processes, though this has been limited mainly to administrative processes ([10-12]).

Otherwise, for more than a decade, reports from expert panels have called for improvements in science education. There is general agreement that science courses consisting of traditional lectures and cookbook laboratory exercises need to be changed [13].

2. Methodology of Research

The methodology of this paper is based following three phases as showed in figure 1.

1. The first pillar deals with the lean manufacturing laboratory simulation. This part includes the description of initial manufacturing process situation given to students and accompanying work rules. It contains the structural design of chosen products, proposed workstation assembly tasks, a proposal for an initial layout of manufacturing process and necessary resources.
2. The second pillar concerns the ability of students to join management and financial control to laboratory simulation
3. The third and last pillar was about measuring student's creativity and innovation.

The case study of this research has been simulated on three teams of dozens of students.

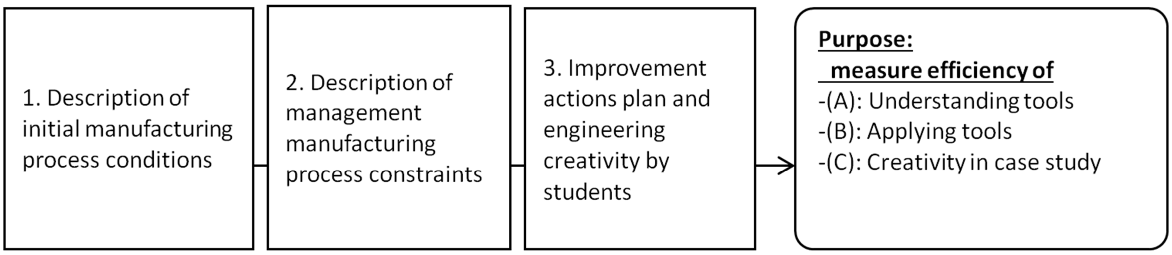

Figure 1. *Methodology of the research.*

3. Case Study

In this section, the new approach of lean teaching process is presented following a case study aiming efficiency measurement of results. An efficiency comparison between classical teaching and LBD approach is made basing on presented criteria A, B and C (figure 1). The LBD case study is based on a lean teaching simulation, in this phase the choice of the process is based on works of [2]. A component assembly process is chosen to allow students to evaluate the losses. and gains and set up lean manufacturing in a non-optimized production process. Figure 2 shows the component used and the assembly process initially started.

In order to evaluate students and compare results with classical approach, input data of the process are given to three groups, each group is composed of 13 students.

It was necessary that students be aware of simulation rules. These rules may change as it unfolds and according to subjects aimed by the instructor. The game was developed to have three iterations from lean concepts introducing to the improvements actions. It was defined to limit time of case study, two simulation phases. A first simulation phase contains problems detection and first product handling by operators. A brake time is used to discuss constraints and solving ideas related to Lean concepts. A second phase should be the last for mass production to give a final cycle time and road map to perpetuate it in the future.

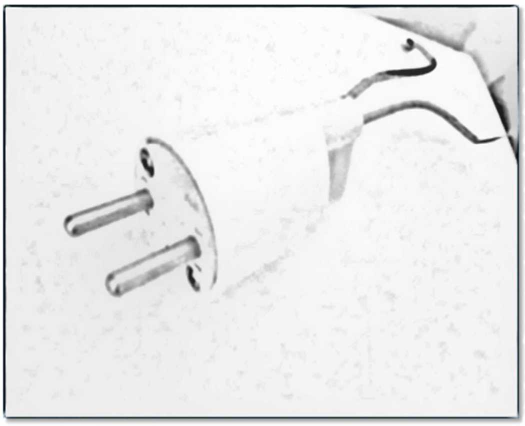

Figure 2. Component used and the assembly process.

3.1. Description of Input Data

The second element describes the manufacturing process which consists of 14 assembly operations including final quality control of assembled product. Those operations are assigned to 6 workstations. Table 1 below shows describes proposed workstation (iteration 1) and related assembly activities.

Table 1. Description of manufacturing work station (ws).

No. of work stations
Work station-1. Preparation of cables
Work station-2. Assembling security parts
Work station-3. Assembling connection
Work station-4. Screwing cables
Work station-5. Final attachment
Work station-6. Quality and safety control

Layout given to students proposed an initial workstations organization and operators disposition, which contains Problematic situation and potential improvement to detect. This simulation is an opportunity for students to distinguish between different layouts and to practice decision making in real manufacturing situation. Initial situation are described in the figure 3.

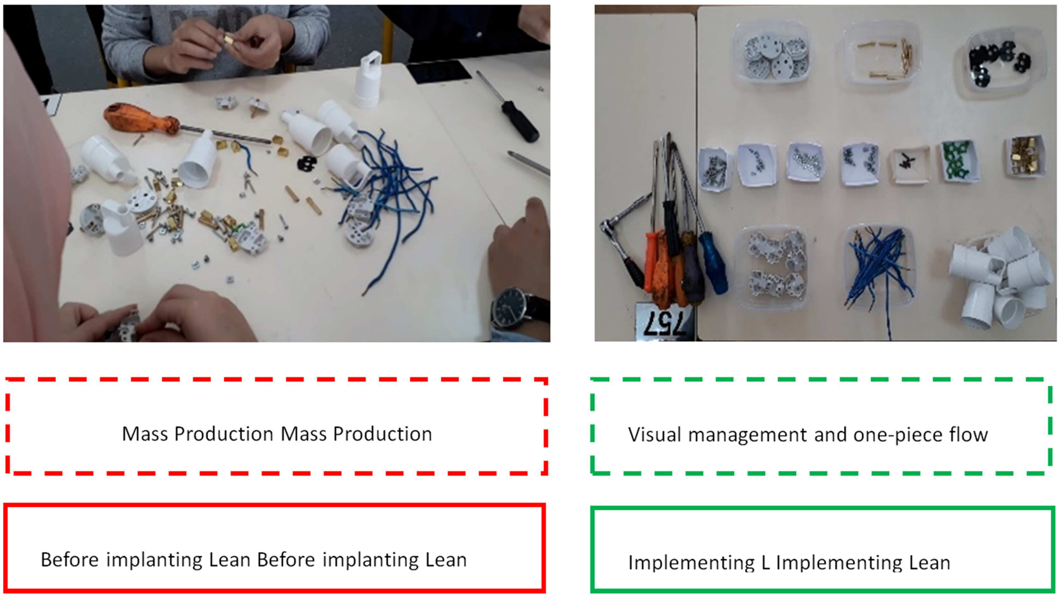

Figure 3. Groups of students are studying process problems and implementing lean.

3.2. Findings

Students applied proposed improvements against detected wastes found in initial process assembly simulation (waste of motion, waste of inventory..). Table 2 indicates that teams in competition have not done the same steps to achieve time saving.

About manufacturing organization work station, all three teams recognized that mass production (MP) is not efficient and moved to one-piece flow production (OPFP). Value stream mapping (VSM) tool has been used to map process after improvements but just one team used Kanban to avoid work station over production.

All three teams were able to make approximately the same number of improvement actions in the second simulation, but they did not achieve the same goal of time reduction. Only the team no1 achieved 50% of time reduction.

Teams no 1 and no 3 has exploited financial data to improve economic indicators in parallel technical indicators as takt-time and cycle time, but only Team no1 has established a production cost saving valued at 47%.

Table 2. Comparison of group's use of lean manufacturing tools.

	Group No.1	Group No.2	Group No.3
Manufacturing organization	OPFP	OPFP	OPFP
Tools used	VSM/Kanban	VSM	VSM
Application Quality of VSM	90%	80%	90%

	Group No.1	Group No.2	Group No.3
No. of indicators used	4	2	4
No. of actions established	6	5	5
Time saving (%)	50%	10%	10%
Computer assisted simulation used	No	No	Yes- Flexim software
Production cost saving established (%)	47%	No	No

As discussed before, the main objective of this case study is to measure efficiency difference between LBD approach and classic courses and tutorials. For this purpose, two sub-objectives have been established, firstly measuring ability to establish lean tools and secondly assessing the LBD efficiency to achieve these goals. A proposed efficiency rate has been introduced composed of six important factors: tools used in implementing lean, time spent in class, number of indicators used, number of established actions using lean tools, percentage of established time saving, computer assisted simulation used. Table 3 below shows these factors as well as proposed efficiency percentage.

After analyzing table 3, it is to conclude that the objective of teaching lean could be achieved, but the efficiency of applying industrial tools as lean tools still be different between LBD and classical approach. Proposed methodology shows that the difference between the approaches could be large and could be exceed 70%.

Table 3. *This table Comapres understanding and creativity measuring rate (UCR) for all the three teams.*

	Classical method	Note / 1	LBD	Note / 1
F1. Tools used in practice	3	0.5	6	1
F2. Time spent in class	8 hours	0.5	8 hours	1
F3. Time spent in practicing case study	0 day	0	6 days	1
F4. Actions established using lean tools	50%	0.5	100%	1
F5. Time saving established (%)	10%	0.1	100%	1
F6. Computer simulation used	0	0	2	1
Efficiency (%)		1.6/6=26.7%		100%

4. Conclusion

The basic contribution of this paper is to propose a new case study about lean manufacturing learning by doing efficiency measurement compared to classical approach. It is to be concluded from this paper, that LBD could be powerful to teach lean manufacturing using few resources. It is also important to notify that courses and tutorials are required to initiate LBD in lean manufacturing.

The proposed tool could be used by researchers and practitioners to have both an idea on simulation training environment and a model to appreciate efficiency of in teaching and training.

Certainly, the proposal can be improved using blend learning approach in lean manufacturing. However, the limitation of the proposed paper is linking and restricting the study of mass production problems. Further research in this field could develop other simulation in SMED and other practical tools.

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