Teaching lean thinking through game: some challenges

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Abstract
Teaching multifaceted concepts such as Lean philosophy to students/employees that have never had any contact with it may be a quite challenging task. The challenge, when teaching students, is to create a context so that they can imagine and understand why Lean philosophy is important and how it can work. On the other hand, when teaching employees/practitioners, the challenge is to translate the Lean thinking into their own context and facilitate their learning process through the different issues of Lean thinking. Overall, the challenge is to create an experience with all the relevant technical as well as social concepts such as: pull production, cycle time, work-in-progress, balancing, teamwork, communication, etc.

This paper describes two Lean games, their setup and associated use of the game. It reflects on the setup up and use of the games, and draws recommendations for future utilization of games in education, having in mind the learning outcomes for the students.

Keywords: games, lean production, students, experiential learning

1. INTRODUCTION

The Lean philosophy, generally expressed as “eliminating waste (in the value chain) with the goal of creating value (for the customer)”, has been (re-) launched in the West during the last 20+ years [1], [2]. Although it has been proven to work and give extraordinary results, the lean approach is still in its early phases of implementation, and “Lean potential has hardly been tapped” [3]. Besides its original context (the manufacturing), the approach is becoming popular in other domains, such as healthcare, administration, IT, etc. Such current situation with the Lean philosophy (its current importance) and wide relevance, gives rise to the issue of teaching this topic to the students and practitioners from different fields. The challenge, when teaching the students, is to create a context so that they can imagine and understand why Lean philosophy is important and how it can work. On the other hand, when teaching employees/practitioners, the challenge is to translate the Lean philosophy to their own context and facilitate their learning process through the different issues of the Lean approach. Overall, the challenge is to create an experience with the relevant technical as well as social concepts such as: different types of waste, pull production, balancing, batch reduction, cycle time, work-in-progress, teamwork, communication, etc.

In the recent years, some of the leading universities (MIT, Virginia Tech, etc) have developed training simulations in order to support the teaching/learning activities concerning lean approach. A survey of simulation tools and training programs in lean manufacturing [4] shows that in 2003 there were 17 simulation activities used in various lean training programs. The majority of these simulation activities simulate manufacturing environments. During the last few years there is also a significant need and initiative to transform the manufacturing concept of Lean thinking into hospitals’ context, and therefore scarce number of games has emerged in order to transform the concepts into the healthcare context [5].

At the Department of Production we have recently started to use games as a tool for teaching lean concepts. The audience has been both students from manufacturing area, as well as from building industry area. Besides teaching to students, we have had an opportunity to introduce the lean philosophy to healthcare professionals, and therefore we have created a Lean game with healthcare context. From our scarce experience in using games with students, we attempt to draw recommendations for planning and conducting games in order to increase the learning outcome for the students.
In this paper, we present two Lean games, their setup and playing, as well as the learning experience of the students. We also reflect on our own experience from setting up and guiding the games, and we draw recommendations for future utilization of games in Lean concepts education, by having in mind increasing the learning outcome.

2. LEAN HOSPITAL GAME

This game was created in order to reflect a healthcare context. The main purpose of the game was to give the students/practitioners an experience with the Lean way of working, having in mind that such audiences (especially the healthcare professionals) usually do not have any knowledge about concepts in production planning and control.

2.1 Setup of the game

The hospital game has 6 roles/departments at the beginning of the game. In addition to this, there is one role of a general practitioner (customer) who refers patient every 15 seconds during one round, by pulling a card with the picture of the type of patient (or diagnosis). One round of the game lasts for 12 minutes (corresponding to 1 day). The game can be repeated 2 or more rounds, each round introducing different conditions and improvements. The aim in the hospital is to treat as many patients as possible, and to treat them right.

The hospital treats three types of patients with: red diagnosis, yellow diagnosis, and white diagnosis. Each type of patient is represented by a specific Lego construction where the colours and the exact shape of the construction are important. An example of a “patient with white diagnosis” is given on figure 1.

![Figure 1. Lego construction representing a patient with white diagnosis](image)

At the introduction of the game the forecast for different types of patients is given:
- 66% are patients with white diagnosis
- 17% are patients with red diagnosis
- 17% are patients with yellow diagnosis.

The hospital consists of the following departments (roles): sign- in and out, preparation, X-ray, surgery, record and quality, transportation. For each role, special conditions for work are set at the beginning: patient handling time, capacity for handling patients, possibility to treat same/different type of patients at the same time, etc. Each participant has a timer to measure the prescribed cycle time.

After each round, the following parameters of the process are measured:
- Number of referrals
- No. of referrals treated
- Referrals treated on time
- Referrals treated late
- No. of quality problems/mistakes
- Special referrals on time
- Special referrals late
- No. of referrals not treated
- Cases in transit
- No. of treatment room/beds
- No. of staff
- Time for patient – throughput.

Furthermore, a financial measure (cost) is associated to most of the parameters (for example, a late treatment would cost 8,000 dkk.).

With such a setup, some of the main concepts from the lean philosophy (WIP, bottlenecks, flow, push vs. pull, overproduction, collaboration, defects, etc.) have been translated into the healthcare context.
Before starting the game, the tables for each role are positioned as on figure 2.

2.2 Playing the game

The game and the experience from it described below has been played with one group of 6 students.

Round 1

At the beginning of the game there are already 5 patients (3W, 1R, 1Y) ready to sign-in. The Sign-in/out (SI/O) role admits patients from the General practitioner (GP) and sends the bottom plate (whose colour denotes the type of diagnosis) to the Preparation (P) department. SI/O also signs-out treated patients in the same order as the patient type (diagnosis) referred from the GP. The P role makes the construction appropriate for this department and for each type of patient, and attaches it to the bottom plate. The handling time for this role is 30 seconds and the capacity is maximum 8 patients at the same time. The three types of patients can be handled at the same time. Ready patients are sent to the X-ray department by Transport (transport can be carried out only if there are 6 patients to be transported). There is 30 seconds cleaning time between two handling cycles. At the start of the game there are already 6 patients in the X-ray department (4W, 1R, 1Y). This department makes the appropriate construction and attaches it to the component delivered from P. Ready patients are sent to the Surgery (S) department by Transport (transport can be carried out only if there are 6 patients to be transported). The cycle time at S department is 60 seconds. There is a capacity of 8 patients to be treated at the same time. Patients with white diagnosis should be together, and patients with red and yellow diagnosis can be mixed. Ready patients are sent to Record and quality (R&Q) department by Transport (transport can be carried out only if there are 6 patients to be transported). R&Q checks if patients are treated correctly (bricks are assembled in the right way), as prescribed for each patient type. Patients that didn’t get correct treatment are collected in a separate “room”. Patients with the right treatment are sent to SI/O.

After finishing the first round, the students enter the parameters of the process into an Excel file (on the Power Point presentation) and can see the financial outcome after the first round (for example, -819 000 dkk). They end up with very few patients treated (for example, 3 out of 47 possible), and a quite large number of patients in transit (for example, 35). The instructor encourages them to reflect on the round by asking what happened and what they experienced, what created value and what didn’t, where the main problems were. After the first round, the students can choose up to 2 out of 5 possible improvements for the next round (for each change in the process a certain financial value is allocated).

Round 2 and after

The second round differentiates from the first one in the improvements the students have chosen. For example, the students can choose new layout and flexible staff. The second round ends with much improved but still poor financial situation (for example, -263 000 dkk), with much more treated patients (33 out of 47 referred), and much less patients in transit (20 compared to 35 in the first round). The students are encouraged to reflect again, as well as to choose improvements for the next round. They choose for example, new surgery room/possibility.
for more parallel treatments (because that is where the largest bottleneck used to be created). At the third round a special patient (different than the previous three types) may be referred by the GP, which creates some amount of confusion, since the group has just paid attention at the forecast and started to use it in their planning of the work. However, the number of treated patients at the end is significantly increased (43 out of possible 48), and the cases in transit is significantly decreased (11). After the third round of reflections and improvements (fusion of departments) the students manage to come out with a positive financial result (258 000 dkk). Approximately one hour reflection followed after the last round of the game to summarize the ideas behind lean way of work.

2.3 Learning from the game
After more than three months, the students were asked to fill a questionnaire reflecting on what their experience was and learning from the lean game. All of them noted that the most valuable thing was that they could experience the importance and the effect of the different types of waste (waiting, transport, and overproduction). They also realized how they can improve the processes to deliver on time, by improving: the communication and teamwork, by continuous improvement, flexibility of the staff, of the different processes and of the capacity, by a good layout, and using the forecast. They learned that they have to deal with the quality throughout the whole process, not just at the end, and that it is important to discover the bottlenecks and improve the processes at that point.

One can conclude that the students have pointed out the relevant concepts under the Lean philosophy and that those concepts have been understood and learned, since they could recall them being asked even after three months.

2.4 On the setup and the game itself
The findings in this subsection are based on the questionnaire given to the students three months after they played the game. The students were asked if they minded that the game was from the healthcare context or would prefer that it was from their own engineering context. None of them minded; they even found it fun. One of the students noted that he was trying to do as good as he can since he considered “patients” in his mind. However they proposed ideas that they would like to play it in the context of computer factory or car production (using small cars instead of Lego).

The setup of the game was considered good. One proposal was to have more than one team. All the students experienced that they were more comfortable after the first round of the game, when they realized better the rules and what the game was about. They also had to become familiar with using the timer as well as making the right components with the Lego bricks.

The students noted that they learned a lot from the reflections between the rounds especially by focusing at the problems after each round and reflecting on which improvements to make for the next round. One suggestion for improvement of the game was that more challenges are needed in the latest rounds of the game in order to test the flexibility and the speed of the system.

3. AIRPLANE PRODUCTION GAME
The purpose of this Lean game is to get the participants to realize the power and benefits of creating flow in the working processes. The game is played in four rounds each of them demonstrating traditional layout, cell layout, single-unit flow with pull, and balanced single-unit pull production, respectively. The main product in the “factory” is an airplane built by LEGO bricks.

Round 1:
The work is organized in a way that the working stations are located where ever there is space (different rooms, offices etc.) and the order of the working stations (functions) is not considered with regard to the product. The work is done in series of production. The storage of material is located away from the working place, the workers are paid individually according to the individual production, the material is carried from one working station to the other, there is big work in process which gives push in the flow, the workers are divided by function, causing bottlenecks, and the quality assurance (QA) is not existing or is performed only at the end of the flow. The outcome of this round usually is quite low, approximately 5 pieces in 6 minutes.

This setup is simulating different areas from the real life, for example:
- Architects and engineers designing buildings, workers located in different offices, with a sharp borderline between the functions, only performing QA in the last part of the work.
• Administrations/offices where the workers are located far away from each other, people are busy doing things right as usual, no time for optimizing
• Production companies where the machines are located far away from each other in various orders. QA in the last part of the work.

*Experience after round 1.* The participants in the game can experience the following
- Low efficiency, due to the distance between the stores and the working stations.
- The participants are very busy doing the wrong things right.
- There is no time for development.
- Lots of bottlenecks.

**Round 2:**
The production in this round is in series of five units. The working stations/workers are located in logic order, cell layout; there is still push in the flow, large work-in-process storage, and QA in the last part of the work. The outcome after this round is improved to approximately 10-14 pieces in 6 minutes.

This setup is simulating the following real life situations:
- Architects and engineers designing buildings, the workers are located in joint project office, with a sharp borderline between the different functions, only performing QA in the last part of the work.
- Administrations/offices where the workers are located logically according to the workflow, people are busy doing things right as usual, no time for optimizing, everyone has its own way of doing their work, and own store of papers etc.
- Production companies where the machines are located in a logical order. QA in the last part of the work, the storage is located next to the working station; there is a large internal storage (work-in-process).

*Experience after round 2.* The participants in the game can experience the following:
- The outcome increases as the storages are located at the working station and as the workers are located in a logic order.
- Still stress due to the bottlenecks.

**Round 3:**
This round is characterized with single unit production with pull, no internal storage of prefabrication, very little waste, still some bottlenecks exist, storage located at the working station, QA is communicated by all group members but the participants can only correct own errors. The outcome of this round is significantly improved, approximately 20-25 pieces in 6 minutes.

Such setup is simulating the following real life situations:
- Architects and engineers designing buildings, the workers are located in joint project office. They are communicating QA from function to function in a joint examination. The borderline between the functions is loosening, they are performing joint planning and following up on the work, and they have some bottlenecks. There is implemented pull in the performing – no internal storages (work-in-process).
- Administrations/offices where the workers are located logically, according to the workflow, people are performing joint planning and following up on the work - optimizing QA is communicated from all workers to each other, there is implemented pull in the performing – no work-in-process, they have bottlenecks.
- Production companies where the machines are located in a logical order. Employees are communicating QA between functions. There is implemented pull in the performing – no internal storage. They have bottlenecks.

*Experience after round 3:*
- The outcome increases as the series goes from 5 to 1 unit at the time.
- No in-process storage gives better quality by paying a little more attention to each unit.
- The sub-optimizing stops as you are not allowed to work ahead to gain more salary for yourself. Pull is implemented.
- Still stress due to the bottlenecks.

**Round 4:**
Balanced production (single unit) with pull, no bottlenecks, storages located at the working station, all participants are obligated to perform QA, communicate QA, and correct own and other participant’s errors in the entire process. In the last round the outcome is approximately 35-40 pieces in 6 minutes.

This setup is simulating the following real life situations:
• Architects and engineers designing buildings, the workers are located in joint project office. They are communicating QA between functions in a joint examination, and every one can correct errors from function other than their own. The borderline between the functions is loosening, they are performing joint planning and following up on the work, and they have no bottlenecks. Pull is implemented in the performing – no work-in-process, no wastes, all the work is performed by the most competent worker and there is no double work.

• Administrations/offices where the workers are located logical according to the workflow, people are performing joint planning and following up on the work - optimizing QA is communicated from all workers to each other and every one can correct errors from other functions than their own. There is implemented pull in the performing – no internal work-in-process. They have no bottlenecks. All work is performed by the most competent worker and there is no double work.

• Production companies where the machines are located in a logical order. They are communicating QA from trade to trade, and every one can correct errors from other function than their own; there is implemented pull in the performing – no internal stores of prefab; they have no bottlenecks. All work is performed by the most competent worker and there is no double work.

Experience after round 4: No bottlenecks gives less stress, and a surprisingly far better outcome.

3.1 Learning from the game
After the game, a questionnaire was sent to the students asking them to reflect on what they learned from the game, and what their experience was. The learning points have been summarized as follows:
- From round 1: lot of waste of time to get the semi-manufactured products from one process to other; errors made from the beginning, not discovered to the end.
- From round 2: better flow; waste of time reduced; still bottlenecks.
- From round 3: more efficient to make one piece at a time; better team spirit when having pull production; better opportunity to discover errors; placing the processes in the right order results with decreased transport time and shorter production time; less semi-manufactured products.
- From round 4: flow can be improved significantly when tasks are divided evenly between processes; large difference on the amount of produced finished products.

A general issue evident in the reply was that the students focused more on what were the problems/effects at each round, rather than why they were happening and how they could be improved. However, they all got the same experience that the lean way of work is more efficient and gives more finished products, and less scrap.

3.2 On the setup and the game itself
The students were also asked to reflect on the setup of the game. All the students gave comment that they would like to have better introduction before the start of the game (for example, introducing the concepts that are used in the game), and also better introduction of the rules before each round. They propose that the introduction and conditions/rules before each round should be stated precisely on Power Point slides, instead of just being orally expressed.

Regarding the game itself, the students gave the following comments:
- It was good that they could experience the improvements instead of just being told that “Lean is better”.
- It is a fun way to learn about the lean process, instead of just having a lecture.
- It would be better if everyone could participate in all rounds, instead of observing and occasionally participating.
- They were missing better reflection about what was going on after each round, as well as better reflection in the end about what the difference between the rounds was about.

4. RECOMMENDATIONS FOR FUTURE
The experience by playing these two games with the students, as well as other experience from before, leads us to draw recommendations for the future planning and organizing of Lean games.

4.1 Recommendations for the setup
Number of participants. The instructor/consultant has to be aware of the number of participants before the start of the game. The optimal number of participants per group in each of the two games presented in this paper is 6 and 5 respectively. More than one group may be considered in order to create a competitive atmosphere.
However, if there are more than 3-4 groups in one room, at least two instructors are recommended. The best learning effect is achieved if all the students/practitioners play the game, instead of partly playing and observing.

**Introduction.** The introduction for each round should be given before the start of each round, instead of presenting the complete game at the beginning. This is because there is a considerable amount of information for the whole game, as well as because some instruction should come as a surprise. An initial training by building the airplanes (for the second game) is recommended. There is a lot of noise in the room because of the Lego bricks and the excitement, when the game is started, so it is recommended that new instructions are not given before all bricks are back in the storage, otherwise no one can hear the instructions. Other recommendation in this line is that instructions are made on Power Point slides and clearly presented to the participants, instead of just verbally expressed. When planning the setup of the game, the instructor has to bear in mind the experience and knowledge of the participants regarding Lean philosophy. If the knowledge is very low or does not exist, it is better to introduce the basic concepts and ideas behind Lean philosophy at the beginning, as well as between different rounds. This introduction will hopefully improve the reflection process later in the game as well as the understanding of different concepts.

### 4.2 Recommendations for playing and increasing the learning

**Reflections between rounds.** Besides the experience that participants will get from playing the game, the learning is significantly improved by reflections between two rounds. This process of reflecting can be initiated/facilitated by MS Excel worksheets projected on the wall of the room. Participants need to insert the different parameters of the round in the worksheet, and this should be repeated by each group (if there is more than one group). This is much more efficient way for learning and reflection, than just giving each group a piece of paper with a table where they have to fill the parameters of the process. Furthermore, it seems that the students may learn better about what needs to be done if they are given a possibility to choose improvement steps for the next round, instead of just telling them what to do in the next round. More precisely, there will be a difference in the learning if the students themselves come to a conclusion that they have to make flexible layout, instead of prescribing to them that in the next round they have to sit in a certain order. In the first case they understand better why they have made certain choices, while in the second case they only understand what a certain choice may lead to, but do not reflect on why they had to do that. Furthermore, in the case of two or more groups that play the game, the learning can be enriched because different groups may choose different improvements for each round. The effects of each choice can be reflected upon and analyzed between the rounds. The instructor should facilitate the reflection between the rounds by considering connections between different concepts, as well as how different issues influence the process.

**Reflections at the end of the game.** Summarizing what happened during the whole game, and why it happened, is a valuable learning step. At this point, experienced instructor has to stimulate and facilitate the students to make all the connections between the concepts. This phase is a “must” if higher conceptual level of learning is to occur.

### 5. CONCLUSIONS

Lean games are effective method of conveying the main ideas and concepts from the Lean philosophy to the students/practitioners, even if they have not been previously introduced to them. We have described two different games, as well as our experiences from playing those games with students. We have reflected on the setup of the games and the playing, as well as gathered feedback from the students regarding their experiences from playing the games. Finally, we have drawn a set of recommendations for future setup and playing of Lean games.

One of the main findings in the paper was that the learning is significantly improved by well planned reflections between different rounds of the game, as well as reflections in the end of the game. In order a deeper level of learning to emerge, the reflections need to focus not only on what was happening, but also on why things were happening. A better understanding of the concepts and the Lean philosophy will emerge if the game’s set-up leaves an opportunity for the players to choose a direction for each of the rounds, instead of prescribing to them what should be done.

### References