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LEARNING LEAN PHILOSOPHY THROUGH 3D GAME-BASED SIMULATION

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ABSTRACT

Due to the increasing innovation of teaching methods, such as Problem Based Learning, new tools for education are increasingly demanded. One that already proved to be very useful, is the game-based teaching approach. As we know the games are a good to improve students' absorption, especially in the engineering courses. However, most of the engineering games need to make use of simulation to handle the complex reality where the students will apply their theories. In turn, Lean Manufacturing is an important concept for engineering courses, mainly for Industrial and Manufacturing Engineering. This is why we developed a simulation game-based approach to teach, through Problem Based Learning methodology, the Lean tools. The integration of the game with a simulation tool is useful for Lean and simulation beginners, who will be in contact with tools in controlled scenarios and will improve their knowledge on evaluating them in stochastic and more realistic scenarios.

1 INTRODUCTION

The game-based teaching has been increasingly growing in formal education over the last decade. One of the reasons was that it can be utilized in many inductive teaching methods (Prince and Felder 2006), exciting the receptor and doing a better interaction with the teaching method . The inductive approaches still being successfully used in medicine for a long time (Albanese and Mitchell 1993) and others health studies are now becoming more and more utilized in the exact science area, for example in engineering studies (Smith et al. 2005). However, as some situations of engineering are difficult or expensive to emulate the game-based methods, especially the simulation ones, the inductive approaches re becoming popular, as they can easily provide reality and be interactive.

On the other hand, one of the main topics in industrial process improvement are Lean Manufacturing, largely studied in engineering course, mainly in Industrial Engineering courses. Despite this, Lean Manufacturing has been taught in many schools in a too conceptual mode, mainly in expositive classes. That is the reason to join Lean and Simulation - to make an easily applicable tool for teaching the Lean

Concept. Note that the benefits of interact Lean and Simulation have already been reviewed by Tokola, Niemi and Väistö (2015).

In this context, this paper intends to introduce a new simulation game-based learning tool, focusing on the development of the Lean Manufacturing skills and philosophy, not only transferring theory, but enabling the future Lean professionals to understand the complexity of the systems that might be under their decisions. For example, through the simulation game the leaner can observe the impact of stochastic times in their production capacity, instead of only calculating the average.

This paper presents a brief review in the Section 2, then in Section 3 it describes the game and its objective. Section 4 shows how the game, developed in Discrete Event Simulation Software, can help the students to understand and train the complexity related to the subject. Finally, we conclude reinforcing the contribution made to improve the Lean learning.

2 LITERATURE OVERVIEW

The use of games to teach is not a recent approach. In fact, games are used to help children learning even before the formal education. Even in management area. In 1961, Cohen and Rhenman (1961) already reviewed the role of management games in education and research concluding its positive contribution to students learning. Note that the focus area of this paper, Lean, is very close to management area, as it is an approach that aims to increase efficiency in the enterprise operations.

Prince and Felder (2006), discussing about this tendency, overviewed the main inductive teaching methods used in engineering classes. Methods that Smith et al. (2005) show such as pedagogies of engagement, which are ways to make the student be engaged with the responsibility of learning. One of those methodologies is known as Problem-Based Learning (PBL), and it is the same that we have used to build our game. As the authors discuss, the PBL is student and cooperation centered, making the teacher a guide to instruct the best path for students. In PBL, the student, generally a group of students, receives a problem, and a solution is required. In this process of trying to solve the problem, the teacher will guide the group through the theory needed to find the best way to do it, keeping the interest of students, that are challenged to solve the problem. That helps the students to improve many desirable skills such as positive independence, personal responsibility, teamwork skills and self-training.

As we suggested before, games can be totally aligned with PBL dynamic, even with other pedagogies of engagement. There are many types of games that can be possibly utilized in these approaches; however, many situations in engineering issues cannot be reproduced in real scale. Thus, the games that cover these situations need to be Simulation-Based. Deshpande and Huang (2011) reviewed the use of simulation games in the engineering education, with many examples of real games in use. The author cited that the game interaction, guided by the correct methodology, can development skills that are currently required by the market in engineering profession.

The benefits of combining simulation and PBL are also evidenced by Koray and Koray (2013), that investigated it comparing a control group and a experimentation group through tests. The use of simulation models in teaching-games can really bring advantages, that is why the simulation models can easily generate insights by the situation view, as Gogi, Tako and Robinson (2014) propose.

We should bear in mind that relation between use of simulation game in game-based inductive learning method, remains we comment the relation between simulation and Lean. To clarify that we have two papers that discuss the benefits of joining simulation and Lean. The first, Uriarte et al. (2015), talks about how simulation cope with the lean limitations, as a deterministic approach, that leads to some divergence in this study and their application, mainly when we think about the future states. That is the primordial point to combine these two approaches in a game - represent with more fidelity the situations observed in a real case, preparing the students to face the challenges in their professional life. In this line of thought, Tokola, Niemi and Väistö (2015) review many successful cases of this fruitful combination.

We do not have to go further to observe the profits of the approaches among simulation game, education, and some knowledge area target. We have many examples about these procedures during the last years, as follows: Chwif and Barreto (2003), teaching operations management; Mustafee and

Katsaliaki (2010), with supply game for the entire supply chain; Tobail, Crowe and Arisha (2011), with supply management game, that teaches the main concepts; Constantino et al. (2012), shows in their game the accounting decisions that the operational management need to handle; Mustafee et al. (2015), teaching maintenance concepts; and Roeder and Miyaoka (2015), that present their teaching operations management tools. These success cases show these desirable relations that have grown and gained their space in teaching strategies.

3 LEAN BOARD GAME

The Lean Board Game (LBG) idea begins with the need of training some professionals in Lean Methods. The classical method (expositive classes) was good, but we had the feeling that even after the training, the leaners have had a lot of difficulty to use the theory observed in the practical cases. Then LBG comes to solve this gap. In the beginning, it had only a physical version, where the students utilized a real board to simulate the situation. Next, in 2015, it gained a Discrete Event Simulation version through the Flexsim Software to upgrade its potential to study the Lean in more realistic scenarios.

The game is case-based, that is, the game is focusing on solving a preconfigured case, through the help of the teacher who can direct the students over the game phases. Now, there are two basic models, a small, to apply faster and punctual trainings, and a complete, to help the entire Lean course. Despite this, the game logic and configuration make possible the creation of new cases.

During the game phases many Lean tools are used to handle with game proposed situations. A list of these tools are on the following Table 1.

Table 1: This table summarizes the tools presented in a game, a brief description of it, and a little intuition of how that is applied in the game case.

Value Stream Map (VSM)	**The VSM, is the key tool for a Lean professional, and that is not different in the game. The students are stimulated to use the VSM to map the process and discover where the largest problems are located. That provides a complete overview of the process, bottlenecks and wastes. This tool also includes the use of Takt time and just-in-time concepts.**
The Five Lean Senses (5S)	The 5S are the main Lean senses. To name: Sort, Set in order, Shine, Standardize and Sustain. Every action made by a Lean professional is permeated by these senses. In the game, the student has to reduce the space distances, reorganize the factory and machines as well as the material flow.
Single Minute Exchange of Die (SMED)	The SMED focus on setup time reduction, their ideological objective is the maintenance of the setup time below 10 minutes, for each machine. That provides good gains of productivity, by elimination of some small activities or application of focused 5S.
Pull Flow	That tool breaks with the most common factory model, the push production. In pull flow we utilize strategies like Kanban cards to control the production levels. In the game the student has to calculate the Kanban model to reach better productions levels.
Standardized Work	This methodology was applied to detail the work schedule of operators, for example, sorting their activities and calculating their requirements and time. In the game, we have to adjust and balance the number of operators number with their activities.

3.1 Game Phases

The game sequence is splitted in phases, in every phase an objective was given to the students, that had to achieve or surpass the goals to proceed to next stage. However, those phases are conduced like Kaizen

Events, make the practical teaching of this basis of Lean philosophy. There is a picture of the game, at this initial stage, on Figure 1 and 2 not yet in the optimized scenario.

Figure 1: The original state of complete game-case on board and into the simulation 3D model.

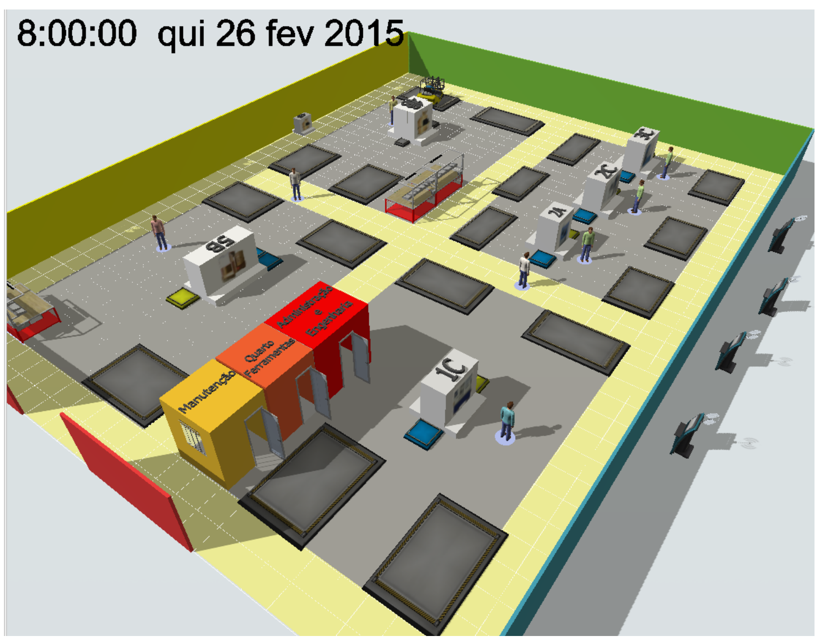

Figure 2: The original state of complete game-case inside Flexsim Simulation Software.

The game is basically a factory with 2 types of final products and 4 types of raw materials. Despite being seen well organized, it has many problems as it cannot produce the total daily demand, it needs more space for another production line, and has had some loss over the time.

The first phase, or Kaizen event, was lined exactly to solve the production capacity problem, and the student's challenge is to suit the production to demand. As we said before, using VSM, 5S, SMED, and some Project Revenue accountings the learner can achieve the objective.

The second problem faced was the space necessity. Again, through VSM, and utilizing 5S and Pull Flow strategy, it is possible to achieve the target.

The last Kaizen event intends to grow the factory's profit. That is when the standardized work is used to reduce manpower necessity. Along these Kaizen events the factory shape alternates considerably. At the end of the last phase the factory meets its demand, has a lot of space and a good profit. A possible new look of the factory can be seen on Figure 3.

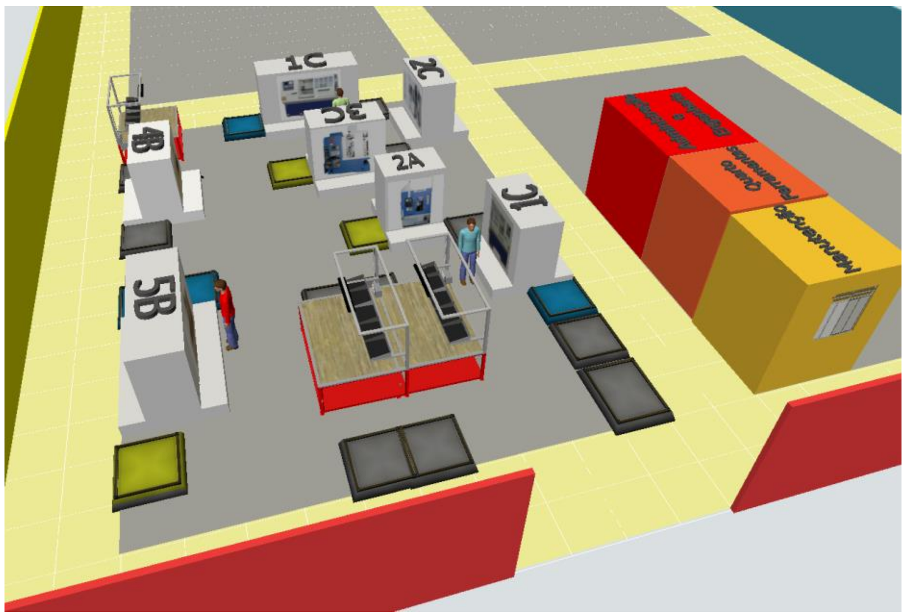

Figure 3: A possible game final state after the three Kaizen events.

3.2 Application Methods

The purpose of this game is to make the students empower the Lean philosophy and tools, utilizing in practice the Lean concepts. The game must have many decision possibilities and ways of following it. Thus, the student could compare the differences of various approaches. In order to the game work like its purpose, the teacher has to be aligned with PBL methodologies. So it is common that the instructor firstly contextualizes the case, in this case the game overview, then shows the first target. Usually the teacher slightly guides suggesting to start mapping the processes. After the students think about it, they expose the theory and monitor the application. That is cyclical. At the end the students will be guided to meet their objectives.

Note that this game is typically applied in a big group of persons. To improve this PBL approach, we divide the group into small groups (3-5 persons), and incite a positive competition between the groups. That way, besides learning Lean, the students improve their group skills and get more motivated to be engaged

Another healthy practice while conducting the group is pause to debrief the knowledge absorbed in every game stage, homogenizing the team. By doing that, we have a complete cycle of PBL methodology.

4 SIMULATION IMPROVEMENTS

For Lean beginners we generally start with a completely deterministic model, following the steps previously described, then they can familiarize to Lean concepts and tools before proceeding to the stochastic stage.

After passing the complete deterministic model, the first elements inserted in the model are still deterministic, such as operator walk acceleration/deceleration, but gives more reality to the model, and shows some attention points that in reality the professionals ignore sometimes. Those simple points impact the model, which has to be reviewed at this point using PBL methodology.

Once passed these phases, we level up the model to stochastic times of processing and setup. And even the advanced Lean professionals have some problems here. These changes, although small, impact directly all decisions made. Then a new concept is introduced, testing the sensibility of their accountings. That redirects to review the system, again using the Lean tools. That is a full experimentation stage. The students make many discoveries by themselves.

The last real element included in the model is the machine smash probabilities, and other occurrences such as operators' absence, and some events during simulation. Newly, we need to review the accountings, that have become more complex at each stage.

At the end of the lessons, we truly believed that the students have had a very close contact to Lean real implementation, and have had to use Lean tools repeatedly times along the game, guaranteeing the concept fixation.

5 CONCLUSION

This paper discussed a game-based learning approach for teaching Lean Manufacturing in a more practical way, following the PBL approach. The classical teaching of these concepts are usually limited to classes expositions, lectures and case studies. However, even the students doing many home projects, they hardly feel as if they are really applying the theory absorbed. That is where the simulation game can help.

We commented that the game is not only for beginner professionals or students, on the contrary, with the Discrete Event Simulation help, the Lean concepts need to be much more evaluated and labored to adjust the situations correctly.

Also, it is valid to mention that some well reputable universities, like University of Campinas (Brazil), has already adopted this game to teach its students the Lean concepts and it is approving the positive results. If you are interested or want to know more about this simulation game you can contact Flexsim Brazil.

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