Lean Games Approaches – Simulation Games and Digital Serious Games

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Abstract—**Training staff is one of the most important aspects of management and is crucial to the success of businesses in an increasingly competitive and globalized world. It is an investment that requires time and money; it needs to be effective and the selection of training methodologies and tools are fundamental to the success of a training program. Selecting the most suitable is not an easy task since it depends on the requirements of the target group and the training goals. This is typically the case for Lean training, where games are frequently used to illustrate the concepts and the application of lean tools. This paper presents and compares two different game approaches to lean training: a simulation game based on a single realistic manufacturing platform, involving production and assembly operations and a digital serious game that replicates a production environment that demonstrate the potential of lean tools. The results show that both approaches promote trainee motivation and knowledge acquisition and suggest that they can be used in a complementary way to achieve more effective learning results.**

Index Terms—**Lean, Simulation games, Serious games**

I. Introduction

Economic globalization presents companies with new opportunities and challenges their creativity and competitiveness in a "survival of the fittest" type environment. More than ever companies are required to find ways and means to improve their performance. One of these ways is by eliminating activities that add no value to their product but which represent a relevant cost [1]. This is the basis of the Lean Manufacturing philosophy [2]. At the core of this principle and differentiating it from other management philosophies, is the involvement of operators in the process of continuous improvement and the notion that when there is a problem one must get as close to it as possible (*gemba, gembutsu, jiu-jitsu*), rather than viewing it from remote office meetings [1][2].

Training all organizational levels in this method is critical for implementation success and, with this in mind organizations have been making a significant effort in this regard.

Universities have also been participating actively in this process, including the Lean Manufacturing philosophy and its tools in their Engineering curricula in an attempt to improve and accelerate their graduates' integration in the organizations, thus improving their chances in the job market [3].

Simulation and games have been widely used to train students and professionals in using Lean tools and demonstrating the benefits of Lean Manufacturing. Although the complete scope of Lean cannot be grasped exclusively through games, they enable the players to experience Lean tools and they foster the discussion, participation and decision making, fundamental requirements to successfully implement Lean Manufacturing, something difficult to achieve through traditional learning methods [4].

This paper presents and compares two different approaches in the development of a Lean training game: a physical simulation game and a digital serious game.

II. Lean Physical Simulation Game

Physical games refer to games that are played in a real space, with physical and real objects, that simulate production environments in a realistic way, where there's interaction and task sharing between players, emulation of staff actions and where the main goal is normally to produce a particular product. In spite of the variety of existing games, their shortcomings raised the need to create a platform that:

- allows to recreate the work environment;

- includes production operations through machinery and assembly processes;

- permits individualized application of different lean tools;

- can easily be embedded in any engineering course by directly replacing a traditional two hour duration class;

- in which it is possible to train students to implement various lean tools without having to introduce and acclimate them to a new setting every time the tool being taught changes;

- is low cost.

Thus, this need led to the development of the Lean Manufacturing Game presented next.

A. Game Description

In this section the core ideas of the game are presented, as well as the developed model and adopted solutions. The developed lean game is a simulation game of a generic production process. Its goal is to enable students to evaluate and experience the needs and impacts of their actions in improving the output of a production

system in a real-life like scenario. The game mode is empiric and matches the most recent practice [5].

The production line in the game produces a pen model in three different colors, packed in boxes of five units each. The goal of the game is to use lean tools to act on the production system to increase the amount of pens made and packed at the lowest cost. The cost is represented by the number of workers in the factory. In each cycle, a different tool is presented and various solutions for improving the game, using that tool, are discussed. From the proposed solutions, the most relevant is selected and executed and a new game simulation begins. After it is finished, indicators are measured and compared to the previous simulation. There is an analysis of problems detected and a new tool is presented, starting a new cycle. This approach lets the participants identify the problems, try different solutions and directly and individually understand the impact each lean tool has in the production system.
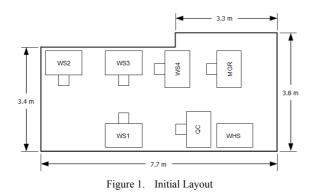
The main goal associated with the concept of the factory is that it represents the conventional workings of a real factory. This establishes a closer connection between the study of lean tools and its object of applicability. The factory in the game simulates a production line through a set of pen assembling and packaging activities, including the making of labels. Fig 1 presents the initial layout of the factory. The factory produces packages of 5 pens in 3 different colors, black, blue and red. The pen model was disassembled to define the assembly process and number of workstations required. From the product tree (Fig. 2), three workstations were established. This configuration was, among others tried, the one with less variability in assembly time. This prevents unrealistic unbalance situations at the outset.

Each simulation is initiated by the Game Master who communicates to the Production Manager (MGR) the product needs. From that moment, the Production Manager informs the other workers of their production and material orders, initiating the flow of information and materials in the factory.

Process flow

The process begins with the production orders and material requirements sent to the Warehouse (WHS) by the Production Manager. The warehouse worker prepares and sends the materials and production orders to the workstations.

In workstation (WS) 1, the lower subset is assembled,

composed by a spring, ink cartridge and lower body. The subset is then transported to WS 3. In WS 2, the upper subset is assembled, composed of button, pin, clip and upper body. The subset is then transported to WS 3. In WS 3, the worker must combine the lower subset, assembled in WS 1 with the upper subset assembled in WS 2. The pens are then transported to Quality control station (QC) where the product is inspected.

Afterwards, the pens are transported to WS 4. In this station the pens are packed. Packing requires boxes, tapes and printed labels (Fig. 3). Printing the labels is part of the packaging process. The finished product is then transported to the warehouse and the finished production orders are delivered to the Production Manager.

Storage

The warehouse consists of a vertical support structure, designed according to the dimensions of the transport containers (see Transport) and to ensure easy access to components. In the vertical warehouse, the components are placed in such a way as to be easily recognized and allow for an efficient supply of the workstations. The components are organized by shelve and color as to be easily found. This configuration and warehouse
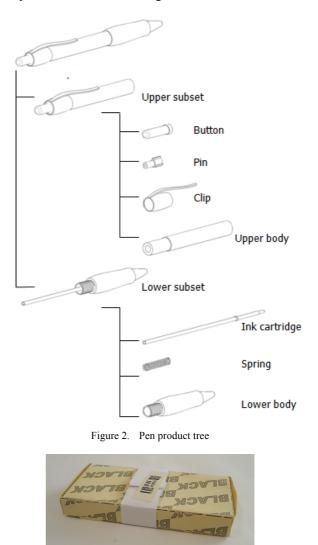

Figure 2.   Pen product tree

Figure 3.   Package

Figure 1.   Initial Layout

organization were designed as an opportunity to implement the 5S tool. 5S is typically one of the first Lean tools that companies choose to implement because the results are almost immediate. Peterson & Smith defined 5S as a working tool to develop systematic planning, classification, order and cleanliness, thus increasing productivity, safety, employee motivation and, consequently, competitiveness [6]. The name of this tool comes from the five Japanese words that define the methodology of work:

- Seiri, which means Sorting;

- Seiton, which means Setting in Order;

- Seiso, which means Systematic Cleaning;

- Seiketsu, which means Standardization;

- Shitsuke or Shuukan which means Sustaining.

Transport

The transport of the subsets between workstations is done using a container specifically designed for that purpose (Fig. 4). The container rack can carry 5 units or, when combined, 15 units. This option establishes the basis for a change from a push type system to a pull type system, using, e.g. the *Kanban* tool (*Kanban*, a Japanese word that roughly translated means a visible record, is a tool developed by Toyota to manage the operational flow of materials in a production system, triggered by actual demand, that is, a Pull System [7]).

The transportation of materials and pens is done via classic containers. The diversity of container formats is useful in experimenting tools 5s and *Mizusumashi* (*Mizusumashi*, a Japanese word for Water Spider, is a person who manages the replenishment tasks to workstations in order to minimize work-in-process inventories).

Assembly

The pen model chosen comes in 3 colors to add complexity to the process. With 3 colors there are now 3 different products which require:

- specifying product characteristics on production documentation;

- coordinating the flow of products and materials;

- changing the setup at the packaging station.

Quality Control

Quality control consists in verifying, in each batch of pens, the following critical characteristics:

- that the color of the pens matches the color of the cartridge;

- that the spring is properly placed.

The inspection is done by sampling after the assembling in WS 3 and before packing.

B. Simulation results

The results were obtained from simulations done by 6 groups of 8 students each (total 48 students) of the Master in Mechanical Engineering course of the School of Engineering, Polytechnic of Porto, during the academic year 2011/2012 [8].

The results obtained in the 1st simulation serve as a reference for the following stages of the game and for assessing the impacts of each of the lean tools in the performance.

From a production order of 150 units, only 40% were completed, and a non-conform unit was recorded. In the analysis of problems the students reached the following conclusions:

- there is no load balancing in the different workstations (creates the opportunity for the line balancing tool);

- workstation 4 has the longest cycle time, representing the production bottleneck (creates the opportunity for the Single-Minute Exchange of Die (SMED) tool);

- all workstations have significant idle time (creates the opportunity for the question: so much idle time and so little production?).

Additionally students identified the following problems:

- the movement of the carrier throughout the game qualifies as "excessive";

- the changing time of the stamp is high in order to meet the production needs;

- the work in process is high;

- idle time in workstations 1 and 2 are due to lack of components;

- idle time in workstation 3 results from the lack of product from workstations 1 and 2;

- there is no organization in the workplace;

- there is an excessive movement of documents.

The waste identified by the students at the end of the 1st simulation has a high correlation with the waste referred to in Lean literature which creates the conditions for presenting and experiencing the different Lean tools.
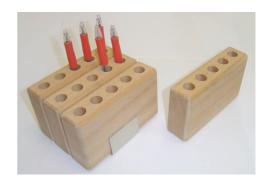

Figure 4.   Container racks

The Value Stream Mapping is the first tool to be presented in the game. Introduces the concept of value and allows analyzing and designing the flow of materials and information required to produce the pens.

Lack of organization in the workplace serves as a starting point for implementing the 5S tool. The time duration of the change of the stamp draws attention to the importance of quick tool change thus introducing the SMED tool (Fig. 5). The SMED tool aims to reduce the equipment setup time [7]. It considers that activities related to setup can be divided into two different groups:

- internal activities, that can be done only when machines are stopped;

- external activities, that can be done while machines are running.

There are four main steps in the SMED tool:

Step 0: Observe and register current setup activities.

Step 1: Separate setup activities into external and internal activities.

Step 2: Convert internal activities into external activities.

Step 3: Improve setup activities (setup preparation and execution).

A Line Balancing tool can be introduced since there is a variation of the average load on the workstations. Excessive movement of the carrier allows the introduction of the topic layout and application of tools such as *Spaghetti Diagram*. The work in progress, the idle time and the shortages of materials at the workstations allows the introduction of flow management tools such as *kanban*. The existence of a workstation for quality control allows the introduction of self-control tools. The existing nonconformities like poor positioning of the spring in the
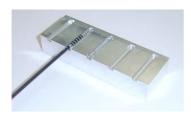
pen allows the introduction of the tool *poke yoke* (Fig. 6).

III. LEAN DIGITAL SERIOUS GAME

By digital serious game, we refer to games that are played in a computer (or equivalent digital system, like a tablet or smartphone) that create a virtual replica of the production environment so that the player only interacts with the virtual elements of the game, not real objects.

The main idea of the digital serious game is to confront the user with a task to be performed using some tools and materials, in a specific workplace. The user has to perform that task in different conditions to understand the need to apply systematically the 5S method.

In the game, the user is confronted with an unorganized work place, with more items than required, without organization and unclean. The user then needs to select the items that the production requires and assign an identification tag (red, yellow and green) to the items according to their importance in accomplishing the task (sort); choose the places where to store the items until the time they are needed (setting in order); clean the work place of the unnecessary items (systematic cleaning); find ways of turning these procedures standard (standardization). The game proposes four completely different scenarios for the user to apply the 5S method: Warehouse; Factory work place; Office secretary; Computer desktop with folders, documents, etc.

By playing these distinct scenarios, the user will interiorize the concepts and practices (sustaining) and he/she will also be alert to the fact that the Lean philosophy can be applied in different situations not just in manufacturing. The last scenario, by its very definition, can in fact be applied to any person that uses a computer, so it will be used as an example to demonstrate the game. The rationale of this scenario is as follows: Why is it so difficult to navigate the file system of a computer? Is it really beneficial or productive to have all documents, pictures or other files scattered in the desktop? What is proposed with this game is that the user applies the 5S Method on a company computer: he has to find a better way to organize files so that they are easily found and retrieved.

The game realistically simulates the desktop in a Windows platform, with standard icons for My Computer,
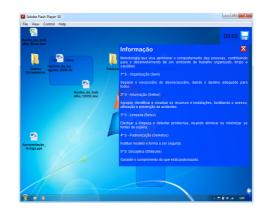

Figure 5.   SMED example

Figure 6.   *Poke yoke* example

Figure 7.   Game enviroment

Recycle Bin, files and folders (Fig. 7). Initially the desktop is crowded with files and folders. The user has to find a specific file (which will take a lot of time due to the desktop chaos. Then he/she has to select the files and folders that are relevant (sort), organize them by relevance (set in order), discard or archive the non-relevant ones (systematic cleaning) and define procedures to maintain this process (standardization). Then he/she looks for the same file. The method of evaluation of performance of the player is based on the use of *spaghetti diagrams*, created by monitoring the position of the cursor on the computer screen.

The evaluation was conducted through a case study methodology. The audience was a group of 15 students attending the Masters in Mechanical Engineering, a subset of the students that played the game. A presentation was made to the students, explaining the objectives and features of the game and afterwards they played it autonomously. Some of the parameters evaluated were collected through observation, while students interacted with the game. A questionnaire was given to students at the end and a series of informal interviews also led to the collection of qualitative data for the study.

80% of the players agreed that the game is intuitive and that the scenario is realistic. However, only 53% considered that the game allowed them to better understand the 5S method. This happened because the group that evaluated the game consisted of students who already had experience in this area and the game only deepened that knowledge. 67% of the students said that the game motivated learning the content, 93% considered that this approach should be applied to other topics of Lean and 100% considered that games like this are an asset in training.

72% of the students considered that the scientific and technical quality of the game was high but that it should be more detailed, providing more information. However, talking informally after the evaluation, they said that if the application was directed to students who are starting to learn this content, the depth is appropriate.

It was concluded that although there are a few Lean digital games and several Lean real games, 66% of the students had never played such games.

Overall, there was a good atmosphere in the room during the evaluation and four or more players played the scenario more than once. All players ended the game. There were no incidents to register. In summary, the results exceeded expectations, with a great acceptance of the game by the group.

IV.   CONCLUSIONS

This article proposed two approaches for improving the motivation and effectiveness of training through the use of simulations and games: on one side, a physical simulation game that reflects the reality of a factory and that requires the intervention of the students to apply Lean tools to improve the efficiency of the production line; on the other side, a 5S lean tool digital serious game.

After the evaluation of the implemented games, it is possible to conclude that they are both motivating tools

for learning and acquiring the proposed knowledge. Students were actively engaged in the games, they enjoyed the learning process and the resulting knowledge acquisition was clearly observed. Furthermore, it is possible to see that both games can be used complementarily therefore reinforcing the individually acquired knowledge.

The future work involves the development of the digital serious game to a level of higher complexity and more detailed information, and including more Lean tools in the simulation game, as well as evaluating and comparing its efficiency as a teaching tool, when used independently or as a complement to traditional classes, using control groups.

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