SIMULATION FOR TEACHING THE PRODUCTION CELL CONCEPT IN CIVIL PRODUCTION ENGINEERING

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ABSTRACT

Simulations are instruments that can help the teaching process. The present study develop a simulation as an academic teaching tool and create a method for teaching the production cell concept for students of Civil Engineering course. Besides, the model seeks to teach about productivity, quality and waste on construction sites. The methodology is based on: (a) theoretical review about the use of simulation as a teaching didactics for engineering students; (b) prototype development for the simulation; and (c) a pilot study. The simulation consists on implementing a reduced physical model, in two dimensions, of a house using color paper cutting and collage. Three rounds of simulation are implemented, where they are taught the concepts in a continuous and gradual way. The use of three rounds has the purpose of allowing the comparison of data, productivity, quality and waste on the house construction highlighting its improvement with the introduction of the production cell use.

Keywords: cellular manufacturing, simulation, teaching

1. INTRODUCTION

The classic approach on education, based on traditional methods of knowledge transfer has clear efficiency limitation. The use of experimental active form of teaching that stimulates students to think creatively and act correctly brings more value to their education. (PURNUS; BODEA, 2015).

The teaching of multifaceted concepts such as Lean philosophy for the students and employees that had never had any contact with them can be a difficult task. The challenge when teaching students is to create an environment so they can imagine and understand why the Lean philosophy is important and how it can work (DUKOVSKA-POPOVSK et al, 2008). According to Romanel e Freitas (2009), to a better understanding of the Lean Construction, it is necessary to implement new learning tools. Games and simulations, which are still innovation for this purpose, fill that gap. Therefore, a field for game development is noticed, allowing content transmission in a didactic and effective way.

A very used tool on Lean manufacturing is a production cell. Its main purpose is to keep the production the closest as possible to the continuous flow. On construction, these tools applications are still rudimentary and they need more studies (MARIZ; PICCHI, 2014).

Therefore, this article has the purpose of showing a simulation development headed for Civil Production Engineer students that provides the production cell concept directed to a practical way of teaching.

2. REVIEW

2.1. Simulation

Simulation and games are tools that support the traditional and formal teaching, being a useful pedagogical resource and that has an educational intrinsic value. These tools bring to the training field for the classroom, practice and experience that are essential to the professional activities improvement (ROMANEL; FREITAS, 2011).

A game can simulate situations close to the reality what leads a participant to look for solutions using concepts and theories presented in class. Implementing didactic games, visualizing processes became easier and can make learning more effective (DEPEXE, 2010).

2.2. Production Cell

According to Rodrigues e Picchi (2010) studies, the Lean Thinking has been gaining more and more space on the Brazilian civil construction sector, and many cases are observed. However most Lean applications at construction flow are restricted.

Rodrigues e Picchi (2010) performed an experiment survey about the Lean Thinking at building construction and identified that the lean tools used more frequently on construction sites are: line of balance, last planner, process standardization, value stream mapping, small batches production, Kanban is a production cell.

According to Patussi e Heineck (2006) motivated and well-trained teams, with a clear responsibilities definition tend to lead their work in a better way. One way to do that is through a cell production formation.

For Hyer e Brown (1999) there must be equipment utilization planning on the production cell, from the similar process parts and the creation of a continuous work. Therefore the tasks and people who perform them should be close in terms of time, space and information.

3. METHODOLOGY

Based on the review about simulation and lean construction tools, a gap was identified on the simulation use for production cell teaching practice.

After identifying the gap, the destination target public was defined, Civil Production Engineer students or Civil engineer with a semester teaching system.

The next step to the simulation developing was the magnitude definition, in other words, the number of students for a team, game of the low cost and easy access material. Besides that it was necessary previously define how many interactions could be made in one semester, develop the simulation object, material and equipment to be used, time and rules for each interaction.

Finally, before using the simulation for undergraduate students teaching practice, it was defined a validating need. The simulation was tested through a pilot study observing the presence of clear information, instrument adequacy, time sizing to perform and the developed object complementation need.

The use of a reduced physical model in two dimensions, without the use of computers, was a choice of the researchers so that the simulation could be applied in environments with few resources.

4. GENERAL GUIDELINES

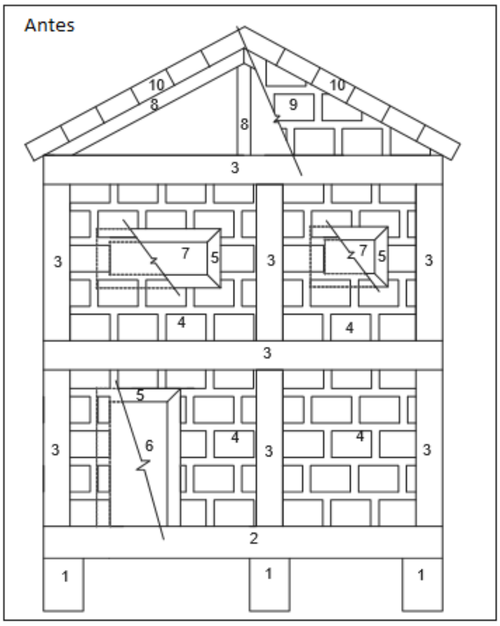
A simulation was developed with the purpose of teaching the Cell Production concept supported by the productivity concepts, quality and material waste.

The developed object consists in a two dimensions reduced physical model of a house, simulating a real execution. For this purpose color paper cutting and collage are used in a "building site". The simulation includes ten activities execution, performed in a linear sequence where each interaction can be completed in a 100 minute class.

The house executive project (Figure 1 (a) and (b)) is a simple representation and its size is not proportional to the size of a real house. This is so that the parties that should be cut and glued can have ruler measurable dimensions and can be easily handled.

The simulation is consists in three iterations. In each iteration, the concepts are taught and applied in a progressive and continuous way, as described by Kaizen. This makes the student absorb the concepts better. In every iteration the same house is executed. By the end of each one, the performance is measured (execution time, quality and waste).

Design project



(a) Instruction project

Figure 1: The house executive project

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The students who participate the simulation should have fulfilled a considerable part of the undergraduate subjects. Therefore, they already have technical knowledge about construction techniques and management. For the two first iterations the students are gathered in groups of four, three are responsible for the execution and one responsible for the execution time measurement and photographic record. On the third iteration, the students work forming a single team that work searching a good result in terms of productivity, waste and quality. At least eight students are necessary to perform the simulation so a competition can be established as a form of motivation.

On the first iteration the simulation rules are explained, but no concept is explained and each group should execute one house. The winning group is the fastest one to build the house. Thus, a construction site situation is simulated where the workers don't receive training and are under pressure to perform the tasks in short terms without a warning about the execution with quality and low waste.

On the second iteration, the students are taught about quality and waste. Now waste minimum levels are shown and quality achieved with a model house execution and executive project details are explained. Each group should execute one house. The winning group is the fastest to build the house with the lowest waste and the best quality.

On the first and second iterations the group organization is the same. Each group organizes the best way they think is the best for the house execution. They should follow the simulation rules, however there is no pre-established definition or training that establishes which function for each student in the group. The classroom organization on these iterations can be seen on Figure 2.

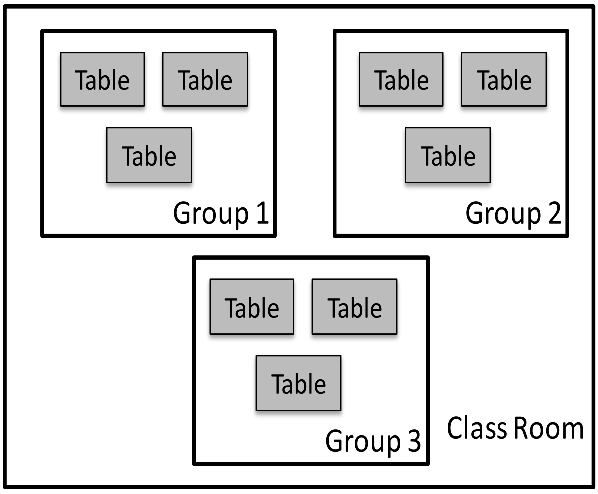

Figure 2: - Classroom organization on first and second iterations

On the third iteration, the students are taught about production cell. For the application of this concept the students are reorganized and trained to perform another function, thus favouring a continuous flow achievement (Figure 3). The number of houses executed is the same as the previous rounds so the results could be compared.

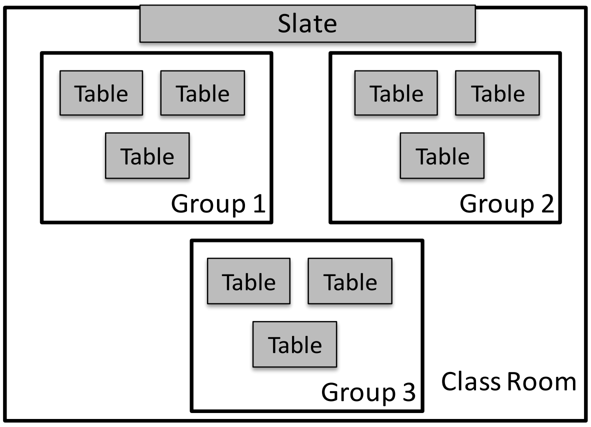

Figure 3: Classroom organization on third iteration

Besides that, the students begin to have function definition (pieces measurement on the executive project; marking the pieces dimensions on colored paper, cutting parts, gluing; marking the activities execution time and doing the photographic record of the activities execution) within the process and the tools designation that should be used. They are also instructed about other tasks so they have action knowledge to perform the activities and when they finish they are encouraged to collaborate with ongoing tasks and in this way they have a systemic view of the process and they work as a team.

The definition of the number of students that will perform each function seeks to allocate more students on the tasks that demand more time. In a classroom with 20 students that execute 5 houses, two students measure the colored paper parts, ten students mark the parts dimensions on the colored paper and cut pieces, three students glue the parts on the construction sites and five students record the houses execution time and take notes on the accomplishment of each activity. So the execution happen in an organized way, the students receive instructions on which house each one should work on first. The houses that should be worked on first are the closest.

The students are kept close to facilitate communication so it is possible to avoid misunderstandings and waiting time. Besides a visual communication tool is used to improve information. For this purpose, an executive project in a larger scale is fixed on the classroom board. The board is also used to take notes of information like for example, the parts dimensions, improving the form of communication. The desks are placed in front of the board allowing easy information view.

The students responsible for elements measurement are placed close to the board. They are the ones who write and explain the information on the board (they are the ones who write the explain information on the board). These students are instructed to inform the others the standards and parts repetition and making the marking and cutting tasks more effective. The standards are the paper colours of each activity and the hatching direction. After finishing their activities, these students help the others observing if the activities are being performed correctly and if the quality and waste standards are being followed.

In order to make the student pairs that mark and cut the pieces work together, some of the colored papers are cut in half. On the first and second iterations each house receives seven colored papers measuring 18 x 10 centimeters. On the third iteration each house receives seven colours of paper, two measuring 18 x 10 centimeters, two with 18 x 5 centimeters and four with 9 x 10 centimeters.

The number of students per task can be adapted based on the number of students participating the simulation. The important is that between rounds the house numbers are kept and that for each house executed, one student is responsible for recording and measuring the execution time.

In order to perform the iterations the students must observe the guidelines that follow:

- the house must be constructed according to the provided project
- the activities execution order should be in accordance with the project established;
- the activities should be performed in series (initiate a new activity only after the previous one has been finished, including the measuring services, dimension marking on colored paper, cutting and pasting);
- the students can only use the material provided to them
- follow each iteration specific rules, if that is the case.

For the house execution each group has at their disposal (figure 4):

- tables
- four chairs
- house executive project
- construction site
- colored paper
- two rulers
- two pencils
- an eraser
- scissor
- glue
- chronometer
- camera
- name tag to identify the student responsible for the execution time marking and photographic record of each activity
- container for depositing the remaining colored paper.

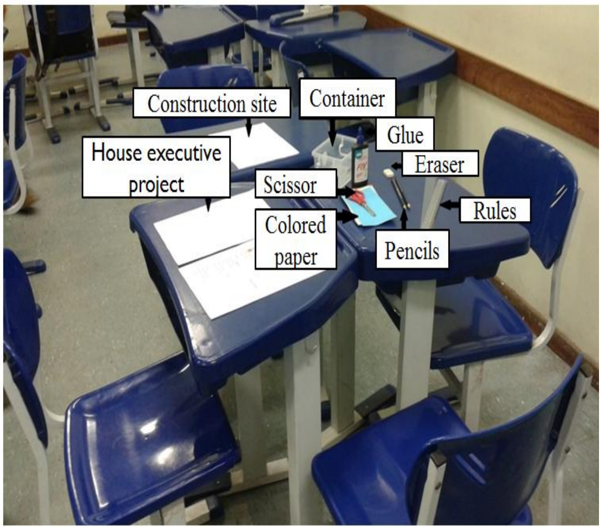

Figure 4: Location of the simulation

The execution sequence of each activity consists in four steps: measuring the project dimensions, mark the elements dimensions on colored paper, cut the elements and paste the elements. Each activity can be composed of more than one piece, with the same size or not. The activity steps can be executed in parallel.

The executive project is the graphic representation in two dimensions of a house cut. On the project the house elements are indicated, a legend indicating the activities execution order and the colored paper that should be used in each one. Also in the executive project there is a field for notes taken from the time spent on each activity. Besides that, the executive project serves as the house elements size source.

The construction site is fixed in one the tables simulating a real construction site situation, where workers move around a single fixed product. It consists in an A4 piece of paper with the house graphic representation with the same size as the executive project. The students should paste the colored paper on it.

The colored papers are provided in predetermined dimensions and on the same amount in order to execute each house. Each paper size should allow the evaluation of its use and its leftovers. Some papers have hatches so the material standardization care can be evaluated. Thus, it is observed if the respective colors are used on the correct activities and if the hatched papers are cut and pasted on the right direction.

The rulers are used to measure the piece's size from each house activity. This measurement should be performed on the executive project determined paper. The sizes measures should be marked on the colored paper with pencil and then cut with the scissors and glued on the construction site. The pencil should also be used to take notes of each activity time execution.

The camera is used to register the events along the iteration. Then, it is possible to observe the execution,

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group organization, material waste and the activities execution quality.

For each iteration, performance identification the execution time is computed, the quality is evaluated and the houses waste. This identification is performed after each iteration is finished. To evaluate the quality, the pictures taken during the iteration are compared to the model house (Figure 5). The waste is evaluated comparing colored paper from the executed house with the paper from the model house (Figure 6). The execution time is determined by the sum of the execution time from each activity, so each house has an execution time.

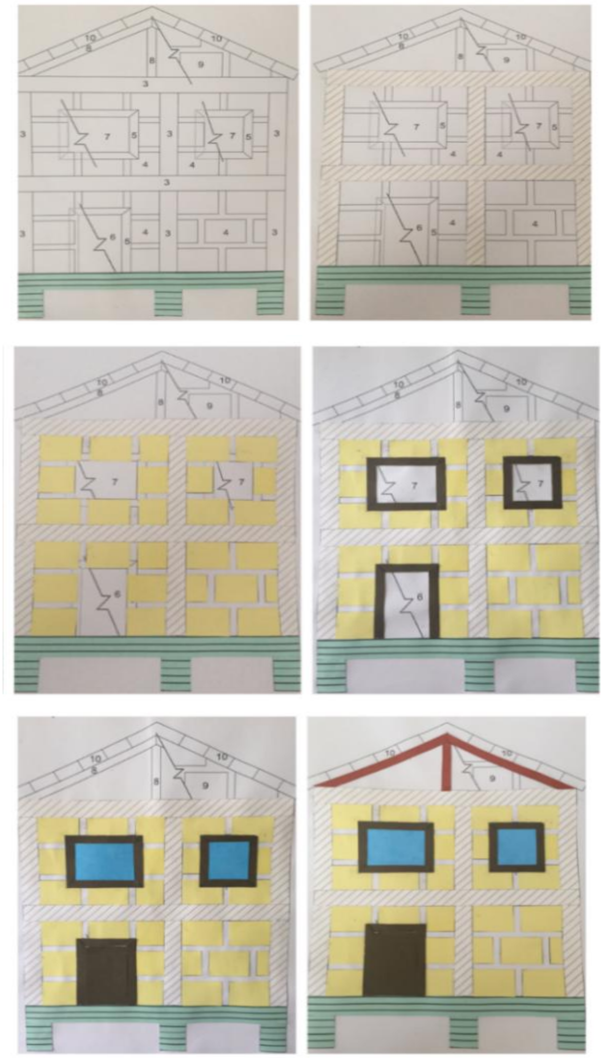

Figure 5: model house to evaluate the quality

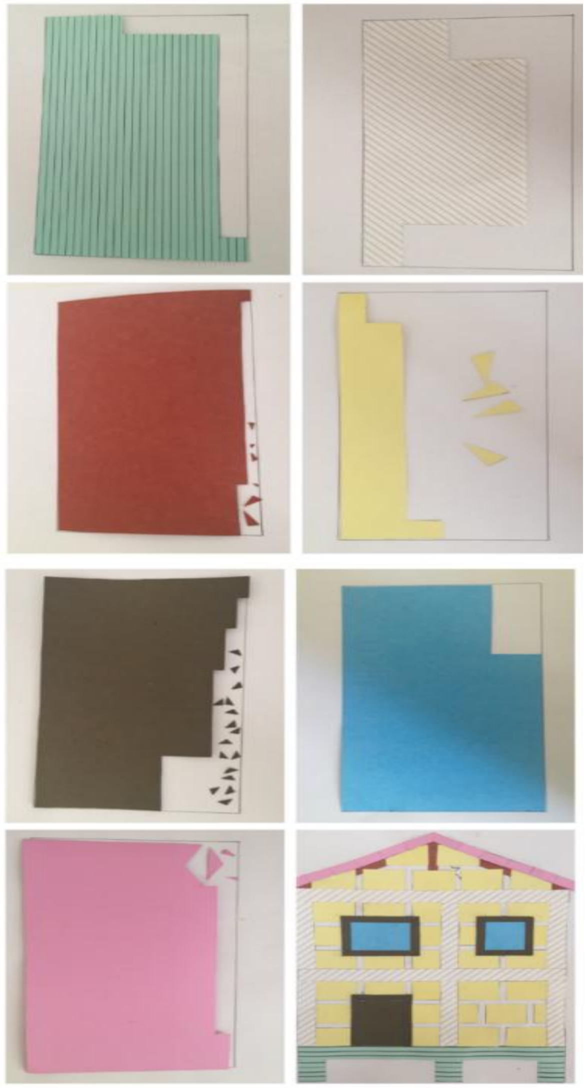

Figure 6: Minimum waste example and model house

4.1. Pilot Study

The pilot study consisted on the simulation application with a group of four Civil production engineer undergraduate students. On this study, the first iteration was applied along with a questionnaire. The questionnaire had the purpose of observing the clarity, gaps and doubts about the simulation.

The first iteration was chosen for the pilot study realization, because probably is the one that demands more time for its execution. This is because there is no training on the execution manner. With its implementation of the pilot study, it is possible to know approximately the longest time to execute a house and then adequate the simulation to its need.

At the pilot study beginning, the students received the material to perform the activities and were instructed about the simulation rules. One student was the inspector and the other three responsible for the house execution. After that, the students began the house construction according to what had been proposed.

With the application of the pilot study, it was possible to observe that the execution took longer than expected. The activity that took the most time to execute was the masonry of the 1st and 2nd floors, about 20 minutes. This occurred because it is the activity that has the highest number of measuring, cutting and gluing. To reduce execution time, the size of the blocks was changed from 1.50 x 1.0 centimeters to 2.3 x 1.7 centimeters, reducing the number of pieces (Figure 6).

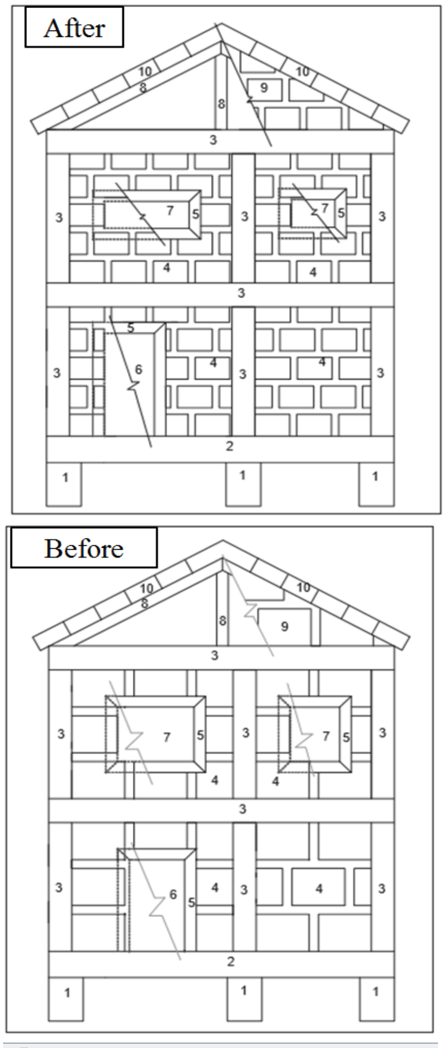

Figure 6: House before and after with adjustments after the Pilot Study

Another measure adopted to reduce the execution time of the simulation was the change in the dimensions of the windows. In the pilot study the windows had different heights and reduced sizes. During the simulation it can be seen that these characteristics made difficult its execution. For the final version of the game its dimension was increased and the heights equaled.

During the pilot study the students had difficulty understanding the cuts that indicated overlapping materials. In this way, for the final version of the game, the cut line was highlighted with a larger thickness and a dotted line was used as a projection form (Figure 7).

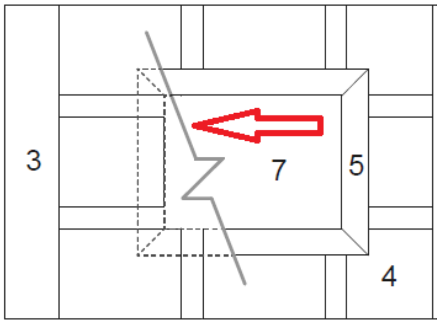

Figure 7: Cutting of doors and windows

Since there was a lot of colored paper left in the pilot study, it was decided to change the size of the material provided. They were 18.0 x 13.0 centimeters and went on to have 18.0 x 10.0 centimeters, reducing waste.

5. CONCLUSION

The use of simulation as a teaching practice brings students closer to reality. The developed game allows students to learn about production cell, quality and waste. In addition, with the use of simulation students have to be able to experience situations where they must make decisions in the search for a more efficient production, that is, they must apply project management knowledge.

In the creation of games, as a means to practice teaching, conducting a pilot study serves to perform tests on its functionality and clarity. After the observations, in conducting the pilot study of the game on production cell, small adjustments could be made and the game can be used teaching way.

The students who participated in the experiment answered the questionnaire. He revealed that 86% of students approve the simulation as teaching practice methodology and declare that they realized the link between staff training with quality and amount of waste.

For the development of this simulation the researchers chose not to use computational methods. Thus, the game can be used in places with few resources. The game can be adapted for teaching people who do not attend universities and can be adapted to run on a computer.

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