Simulator for Lean Manufacturing Applications: Quick Change Case

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Abstract

An educational case implementing a SMED (Single Minute Exchange of Dies) teaching method with results that measure the participating student's perception is reported. This method significantly reduces training time and increases knowledge retention as a result of an improvement aimed at shortening the learning cycle of industrial engineering students learning about lean manufacturing tools. This study was conducted with a hundred students who are the population of industrial engineering in a small college.

Keywords: Simulation, Lean Manufacturing, Experiential Learning

1. Introduction

This research paper addresses the impact of knowledge transmission through the practice of lean manufacturing techniques by means of physical simulation machines. The term 'machine simulation' is used as opposed to 'virtual simulation'.

McManus [1] state that simulation-based learning of complex, lean manufacturing concepts is an active learning mode. It pursues the following objectives: To increase understanding, to improve contextual and holistic understanding, to promote experience-based learning, and to increase student participation and enthusiasm[2],[3],[4]. Other benefits, such as teamwork are also considered.

This research aims to assess retention of knowledge transmitted through the experiencing of lean manufacturing techniques, e.g. quick-change tooling.

1.1 Description of the simulator

The simulator has a workbench, on top of which were placed metal profiles to carry out punching operations to produce designs requested by a customer [5]. This particular simulator produces car license plates. The dies that are appropriate for the manufacture of the design requested by the customer are placed on the workbench. Both tooling and dies are interchangeable, thus allowing adaptation to changes requested by the client.

Initially, students work with traditional elements used to fix the tooling, such as screws of various sizes – similar to those used in industry— with the support of wrenches to secure bolts, nuts and washers.

Subsequently, students learn appropriate technical procedures that reduce die tooling removal times, and improve placement rates for dies and tooling.

The experiment was conducted with students who had no previous knowledge of lean manufacturing techniques. Students interact with the simulator by following instructions in a guidebook, adhering to customer and production requirements, and comparing lean techniques to traditional mass production techniques. Due to the changes which take place customer demands, students will quantify results on a spreadsheet especially designed for this purpose. The spreadsheet results will be used as financial indicators. Without claiming that simply using SMED all production problems will be solved and timely delivery of products will be assured; an improvement of the conditions that allow manufacturing firms to gradually improve their processes is attempted. If industries perform tasks more quickly and accurately, a more competitive position will be achieved in this globalized world.

A first approach to a hypothesis states that the development of a simulator for lean manufacturing applications can mimic actual situations in industry. Once the simulator is conceived, designed, built, and made operational, it will improve teaching - learning techniques through actual experience. This experience will be measured by more specific approaches shown below.

1.1.1 Sample Selection.

The sample was determined from a population of 102 Industrial Engineering students at a small private university. The sample size was calculated using the methodology proposed by Triola [6] which resulted in a sample size of 81.

In order to conduct a quasi-experiment with two relatively equal groups where no work is done by random selection, the students were placed into two groups with intentionally balanced grade-point averages (GPA) and coursework advancement. These two groups were gender balanced. To ensure the balance between GPA, average credits approved, and gender composition between the two group's hypotheses, tests of these variables were conducted and a confidence level of 95% was obtained.

1.1.2 Quantitative Approach

The primary variable was defined as the score on a test of knowledge of SMED (Single Minute Exchange of Dies), which corresponds to questions 1 to 5 of the questionnaire items. We found that knowledge retention is increased by means of the physical simulator as compared to the traditional methods of teaching using Power Point slides.

A five-question test was structured for the students. The questions were:

1 How do you classify SMED time?

2 What is the main characteristic of each type of SMED time?

3 If you want to increase production, which SMED time do you have to reduce?

4 What is the disadvantage of using nuts and bolts in SMED?

5 What else can you do to reduce tooling changeover time?

1.1.3 Qualitative Approach

Greater participation and involvement is achieved from students who receive training through simulation machines than by traditional instruction with slide presentation. The definition of the primary variable is the result of an analysis of the survey conducted at the end of the presentation-and-experimentation, or, experimentation-and-presentation of the SMED Quick Change Tooling technique.

Before the evaluation, slides were prepared and sound was recorded in order to ensure that the presentation time and informational content were the same for all samples.

All tooling, systems and support equipment were prepared for students so they would have everything needed to experience the active Quick Change.

During the evaluation, tooling was provided to the control group. A questionnaire was applied to both groups after either the Power Point slide presentation or the practical experience. The slide presentation time was controlled by timing each slide and a timer was used for the practical experience, so the time spent with each group was equal. See Figure 1.
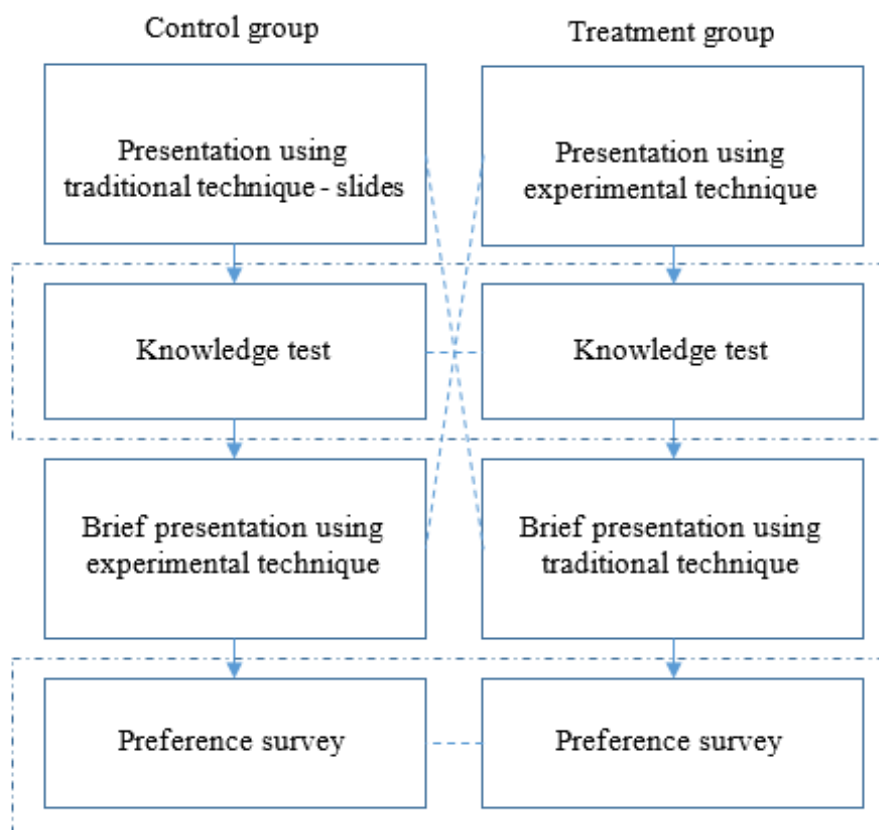

Figure 1. Comparison between groups with different teaching - learning techniques.

After the evaluation, the data obtained from the test and the codification of the surveys was captured. The data as well as the results obtained were analyzed in a consistent and logical manner. The instrument reliability was reviewed. Conclusions were reached and recommendations were made.

1.1.4 Structure of the questionnaire

After the slide presentation, a knowledge test was applied to the traditional slide presentation group. After the test the traditional slide presentation group was briefly exposed to the other technique, i.e. experiential,

and then they were asked to fill out a survey.

On the other hand, the experiential group first carried out the hands-on technique and then were asked to answer the knowledge test, after which they were shown the Power Point slide presentation, and subsequently filled in the survey.

2. Results

It should be mentioned in this section that an important by-product of this paper is the design and manufacturing of the simulator, which allowed us to represent actual industry scenarios and particularly the Quick-Change Tooling technique.

2.1 Quantitative Methodology

The scoring used to grade this test was two (2) points for a correct answer and zero (0) points for an incorrect answer. One (1) point was assigned to each partially correct answer.

The test was analyzed in a comprehensive manner by comparing the total average achieved by the group who received traditional instruction against the group who received Experiential training, and through a test of the hypothesis comparing averages in the first case and variability in the second.

Then each of the answers from the group that received traditional instruction and the group that received experiential instruction was compared. That is, the score average of question one by the traditional group was compared to the score average of question one by the experiential group, and so on. Overall, hypothesis tests are developed by following four steps: The approach of the null and alternative hypotheses, test statistics, rejection region, and both statistical and practical conclusions.

The knowledge test and the overall comparison of each of the questions were carried out.

For the analysis of general knowledge, the following hypotheses are proposed:

H_{O1}, the average scores obtained by the Traditional Slide Group (D), is equal to the average ratings of the Experiential or Hands-on Group (E), $\mu_E = \mu_D$

H_{A1}, the average scores obtained by the Traditional Slide Group (D), is below the average grade of the Experiential Group (E) $\mu_D < \mu_E$

After the experiment, HO was rejected. There is sufficient evidence for a confidence level of 95% to assert that the average grades of Group D are lower than the average grades of Group E. See Tables 1 and 2.

Table 1 Overall results of the knowledge test

		Grade
Total of Traditional - slide group	Average	6.5111
	Standard Deviation	2.4460
Total of Experiential group	Average	8.8222
	Standard Deviation	1.7227

Table 2 Comparative results of each of the questions on the knowledge test

	Question	1	2	3	4	5	Grade
Total for Traditional - slides group	Average	1.4444	1.2667	1.6889	1.5333	0.5778	6.5111
	Standard Deviation	0.8933	0.9145	0.7014	0.8146	0.8391	2.4460
Total for Experiential group	Average	1.8667	1.7778	1.8222	2.0000	1-3556	8.8222
	Standard Deviation	0.5045	0.6356	0.5347	0.0000	0.8300	1.7227

For the rating variability, the following hypotheses are proposed:

H_{O2}; score variability obtained by the Traditional Slide Group (D), is equal to the rating variability of the Experiential or Hands-on Group (E), $\sigma^2_D = \sigma^2_E$

H_{A2}; score variability of the Traditional Slide Group (D) is higher than the average ratings of the Experiential Group (E), $\sigma^2_D > \sigma^2_E$

H_O is rejected at a 95% confidence level. There is sufficient evidence for a confidence level of 95% to assert that the rating variability of Group D is greater than the rating variability of Group E. See Table 3.

Table 3 General Results knowledge test - variance

		Grade
Total for Traditional - slides group	Average	6.5111
	Standard deviation	2.4460
Total for Experiential group	Average	8.8222
	Standard deviation	1.7227

2.1.1 Hypothesis analysis

Analyzing each of the hypothesis, we have:

Hypothesis 1

H_{O3}, the average scores obtained for question 1, from the Traditional Slide Group (D), are equal to the average scores for question 1 of the Experiential Group (E), $\mu_E = \mu_D$

H_{A3}; Average ratings for question 1 in the Traditional Slide Group (D), are less than the average ratings for question 1 of the Experiential Group (E) D $\mu_D < \mu_E$

H_O is rejected at a 95% confidence level. There is sufficient evidence at a confidence level of 95% to assert that the average grade for question 1 from Group D is less than the average grade of question 1 from Group E.

Hypothesis 2

H_{O4}; Average scores obtained for question 2, through the Traditional Slide Group (D), are equal to the average ratings for question 2 for the Experiential Group (E), $\mu_E = \mu_D$

H_{A4}; Average ratings for question 2 Traditional Slide Group (D) are lower than the average ratings for question 2 Experiential Group (E) $\mu_D < \mu_E$

H_O is rejected at a 95% confidence level. There is sufficient evidence at a confidence level of 95% to assert that the average grade for question 2 from Group D is below the average grade for question 2 in Group E.

Hypothesis 3

H_{O5}; Average scores obtained for question 3, by Traditional Slide Group (D), are equal to the average scores for question 3 of the Experiential Group (E), $\mu_E = \mu_D$

H_{A5}; Average scores for question 3 Traditional Slide Group (D) are lower than the average ratings for Question 3 Experiential Group (E) $\mu_D < \mu_E$

H_O is not rejected at a 95% confidence level. There is sufficient evidence at a confidence level of 95 % to assert that the average scores for question 3 Group D are not lower than average scores for question 3 in Group E.

Hypothesis 4

H_{O6}; Average scores obtained for question 4, in the Traditional Slide Group (D), are equal to the average of scores for question 4 in the Experiential Group (E), $\mu_E = \mu_D$

H_{A6}; Average scores for question 4 in the Traditional Slide Group (D), are below the average of scores for question 4 in the Experiential Group (E) $\mu_D < \mu_E$

H_O is rejected at a 95% confidence level. There is sufficient evidence with a confidence level of 95% to assert that the average grade for question 4 from Group D is lower than the average grade for question 4 in Group E.

Hypothesis 5

H_{O7}; Average scores obtained for question 5, in the Traditional Slide Group (D), are equal to the average scores for question 5 of the Experiential Group (E), $\mu_E = \mu_D$

H_{A7}, The average grade for question 5 of the Traditional Slide Group (D) is less than average scores for question 5 in the Experiential Group (E) $\mu_D < \mu_E$

H_O is rejected at a 95% confidence level. There is sufficient evidence with a confidence level of 95% to assert that the average scores for question 5 in Group D are lower than the average scores for Question 5 in Group E.

2.1.2 Measuring attitudes

Referring to the survey, about preferences between the Traditional Slide and Experiential groups, the following questions were asked:

1. Is the teaching - learning process through presentation of slides (or hands-on experimentation),

attractive to you?

2. Does the presentation (or hands-on experimentation) allow you to learn the concepts shown?

3. Does the slide presentation (or hands-on experimentation), allow you to understand its content?

4. Over time, will you remember what you have learned through slide presentations (or through hands-on experimentation)?

5. It is easy to maintain my attention with slide presentations (or hands-on experimentation), in the teaching – learning process?

6. Does the slide presentations (or hands-on experimentation), make it easier to think for yourself?

7. Can you more easily implement what you learned through slide presentations (or through hands-on experimentation)?

8. Can you more easily recognize the importance of rapid change, explained through presentations (or through hands-on experimentation)?

2.2 Qualitative methodology

Quantitative methodology was used. An instrument for students with a Likert scale with four response options (I Totally Agree, I Agree, I Disagree and I Totally Disagree) was used. The choices "I Totally Disagree" (TD), "I Disagree" (D), "I Agree" (A) and "I Totally Agree " (TA) were transformed into a numerical code (-2, -1, +1 and +2) that would:

a) Recognize the bipolarity of the scale - a TA TD - (4 options), and

b) Record the maximum net data for each statement and its valuation in the set.

The resulting value varies for each statement, ranging from 100% for the highest positive attitude to -100% for the lowest negative attitude.

This process of "mutual assessment" of positive and negative values obtains the net trend among respondents.

The survey was reviewed by Cronbach's alpha test. It was concluded that the measurement instrument is reliable. Variance of the items was reviewed, as well as the Correlation Matrix. The result was 0.9065.

The attitude may be interpreted according to the ranges in the following tables. See Table 4:

Table 4 Students' attitudes

LEVEL	INTERVAL
Very good	25% to 100%
Good	0% to less than 25%
Bad	-50% to less than 0%
Very bad	-100% to less than -50%

For the Slide Group See Table 5:

Table 5 Table of results about the group's attitude to the slides

TA	0.0222	0.0000	0.0889	0.0667	0.0444	0.0000	0.0000	0.0667
A	0.4000	0.5333	0.7111	0.2000	0.2000	0.3556	0.4444	0.5556
D	0.5333	0.3778	0.1556	0.6000	0.6444	0.5556	0.4667	0.3333
TD	0.0444	0.0889	0.0444	0.1333	0.1111	0.0889	0.0889	0.0444
	Group D							
A1	A2	A3	A4	A5	A6	A7	A8
-9%	-1%	32%	-27%	-29%	-19%	-10%	13%

For the Experimentation Group. See Table 6:

Table 6 Table of results about the group's attitude toward the slides

TA	0.8667	0.6000	0.8667	0.4667	0.4889	0.5333	0.5111	0.6222
A	0.1111	0.4000	0.1333	0.5333	0.4667	0.4222	0.4889	0.3778
D	0.0222	0.0000	0.0000	0.0000	0.0444	0.0444	0.0000	0.0000
TD	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Group E							
A1	A2	A3	A4	A5	A6	A7	A8
91%	80%	93%	73%	70%	72%	76%	81%

3. Analysis and discussion

Often when building a prototype, it is easy to lose sight of the goal by working on modifications and improvements to the original proposals, either in materials, forming or cutting processes, in assembly, the fastening system, support and other issues. To keep this procedure from becoming an endless spiral of improvements in manufacturing, which can cause paralysis by analysis, it is common sense to restrict modifications in order to achieve the original goal and meet the original requirements. Without disparaging the improvements made to the simulator, you can keep track of any changes that may be reflected in improved versions.

More than just representing a real scenario, we actually wanted a real live scenario. A student who actually stamps, cuts or bends a material acquires the experience of the resistance and memory of the material by touching, holding, handling and feeling movement restrictions in real industrial environments. Working with pneumatic or mechanical forces when striving to obtain a final product or process, is something that sticks in people's minds. We got as close as possible to real life scenarios.

4. Conclusion.

Firstly, the importance of the technique was based on clearly separating internal and external time, seeking to minimize internal time which does not add value to the process and to maximize external income which

adds value at every step. Grasping these times was essential to ensure that the trainee paid attention to them and implemented whatever was necessary to make the process ever more productive.

At present, the use of programs such as computer-aided design, computer-aided manufacturing and computer-aided engineering (CAD, CAM and CAE) is very common. Working with 3D models, where you can select the material to be made or analyze its capabilities in terms of tensile and compressive force, shear, and bending, among others, allows us to verify the capabilities proposed in the initial design and modify them to reach optimum size sections according to defined constraints. We can make changes easily, basically investing only our time.

New dimensions, new materials and new finishes are shown on the screens of computers. We can even add moving parts and apply forces or pressures indicating the weak parts and parts that exceed the forces that arise.

Building a machine with previously defined dimensions (90 x 50 x 40 centimeters and 20 kilograms), allowed us to set boundaries to avoid creating a heavy, bulky, machine that was difficult to transport or move. Therefore, a machine capable of representing actual processes in industry was built. Processes implemented were stamping, cutting, bending, and punching, by means of a piston supplied with air under pressure and safety systems, to protect the integrity of the operator's hands.

This machine has an air pressure regulator which allows it to vary from 0 to 120 pounds per square inch of pressure (0 to 8.4 kg/cm2 or 0 to 8.3 bar), along with a pressure gauge. It has an adapter to quickly connect and disconnect the compressor, allowing for mobility without the use of additional tools such as wrenches.

With materials such as aluminum or tin the machine can stamp, bend and cut, crimp, punch or shear. All of the above depending on the tooling used, which when exchanged, fulfill the technical objective of study which is the purpose of this paper.

The quick change tooling, through the Experiential technique was implemented to be used by Industrial Engineering students. They were able to experience the use of props that helped change tooling, without taking them a long time. Angles, flat surfaces, slots, open media and open washers were used to bring down the time it takes operators to change the tooling. No matter your gender, once trained, you can work on this technique, practicing this hands-on technique for the exchange of dies or tooling.

The students had previously had the experience of the absence of rapid change elements during which it took them more than 4 times longer than the time it took with the aid of SMED.

Teaching - learning through experimentation, was preferred as compared to the traditional technique using slide shows. The students favored its use and showed a lot more motivation and interest in learning these techniques used in industry and manufacturing highlighting their flexibility and ease of adaptation to the constant changes that occur.

4.1 Original Contributions

The design and manufacture of a machine simulator, which allows the student or operator, to experience real work processes with real materials on real machines has been a breakthrough.

The person receiving the training does not have to interpret that the simulator pieces represent actual parts, work is done with real parts at all times. The same applies to the process and machines, no imagination is

necessary; students are faced with the everyday reality of an industrial process.

The control and monitoring of pressure is real and it is possible to vary it to avoid excessive consumption of pressurized air, generates higher cost in the operation of the process. Rapid change in a machine of such small dimensions is another contribution that helps make it a versatile and lightweight simulator. The two safety valves can minimize the risk of a student getting hurt while operating the machine.

Most clamping devices securing the machine, tooling and controls were specially designed for this simulator. There are no similar parts on the market. Nearly all parts of this simulator were subjected to a coating of zinc and then chrome, increasing corrosion resistance.

There are physical and virtual simulators. The former are activated by means of a personal computer and are as sophisticated as cockpit training for pilots and astronauts. Physical simulators, range from toys or games to actual machines that exist in industry. Our proposal is closer to the latter.

The machine is small, light and versatile, with the possibility of exchanging various types of dies: for cutting, stamping, bending and punching. The simulator allows us to work with the actual product, but with a reduced in size, which helps to control waste, even during training. The product obtained is real and tangible, the simulator works with real processes, similar to those used in industry, in comparison to what could be achieved with a game process. Theoretical knowledge is transferred into practice by means of a lean manufacturing process simulator, highlighting quick-change tooling in this particular case.

Students are attracted by the simulator. The experience of practical knowledge, makes them participants in their own training. However it is important to note that training, no matter where it is held or by what means, does not bear fruit if the skill taught is not practiced regularly. Without continual practice, skills atrophy [7]. This machine allows for regular training, within a budget.

5. References

[1] McManus, H. L., E. Rebentisch, E. M. Muman, and A. Stanke, "Teaching lean thinking principles through hands-on simulations", Proceedings of the 3rd International CDIO Conference, MIT, Cambridge, Massachusetts, June 11-14, 2007 pp. 1-16.

[2] M. Aksarayli and A. Yildiz, "Process Optimization with Simulation Modeling in a Manufacturing System". Research Journal of Applied Sciences, Engineering and Technology, 3(4), 2011, pp. 318-329.

[3] H. Wang, "Involve me, I will understand': How to improve students' understanding in the mathematics course ordinary differential equations". The China Papers, 2004, pp. 64-67.

[4] E. Crawley, Malmqvist, J., Östlund, S. and Brodeur, D., Rethinking Engineering Education: The CDIO approach. USA: Springer Science+Business Media, LLC, 2007.

[5] D. F. Manotas Duque and Rivera Cadavid, L., "Lean Manufacturing Measurement: The Relationship between Lean Activities and Lean Metrics", Estudios Gerenciales, 2007 pp. 69-83.

[6] M. F. Triola, Estadística. (10ª. Edición). México: Pearson Educación. United Nations Educational, Scientific and Cultural Organization, UNESCO. (2010). Engineering: Issues, Challenges and Opportunities for Development. UNESCO: France 2009, pp. 296-347.

[7] Liker, J. K. and J. K. Franz. The Toyota Way to continuous improvement. USA: McGraw Hill, 2011