With the support of the Erasmus+ Programme of the European Union

SBL Example:
Caar Truck Lean Learning Factory:
a problem based case.

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01.

Design Criteria of the SBL Activity

Lecture context

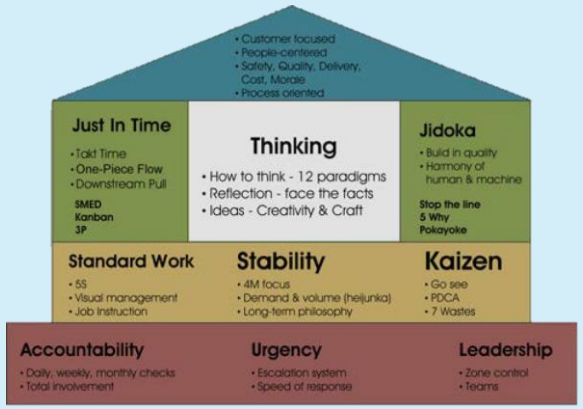
Subject	• Integrated Production Systems
Degree	• Master of Industrial Engineering
Duration	• 3’5 h
Modality	• Truck manufacturing learning factory
Students	• 10-12 students per session, 5 sessions
Working groups	• 5-6 people, two teams

Design criteria

Lecture aims:	• High engagement level • Good real-world mimic
Learning outcomes	• Apply knowledge of lean management operations management to solve a customer demand problem.
Scope of the Activity:	• Students and professionals
Initial knowledge:	• Theoretical base of Lean Manufacturing basic concepts

Initial knowledge

The initial knowledge needed by the participants is a theoretical base of the LM concepts. The students have studied the contents in the previous sessions of the Master of Mechanical Engineering



Lean Manufacturing: Methodology that consists in continuous improvement by eliminating waste from a manufacturing process.

Scope of the activity

The learning activity is aimed at:

- **High education centres who want to teach their students Lean Manufacturing (LM) philosophy and the use of learning factories and problem based learning methodology**
- **Professionals who want to lead, manage, or participate in the implementation of continuous improvement in their production process through LM tools.**

Intended learning outcomes

- **Apply the knowledge learned during the sessions of the master program on lean management in the effective resolution of a complex organizational problem:**

  - ✓ Identify the basic elements and indicators of a production process
  - ✓ Identify and categorize various production problems
  - ✓ Determine the root cause of production problems
  - ✓ Apply knowledge of lean principles and practices to solve production problems.
  - ✓ Plan and implement solutions to production problems
  - ✓ Evaluate the results of the application of solutions

- **Transversal competences: problem solving, team building, flexibility.**

02.

Use of PBLM

2.1.- PBLM Input and outputs

The input of the PBLM are chapters of books related to flow production, cell production design, cycle time, lead time, and takt time

The output of the PBLM are questions and answers that help in the production problem solving apliying A3 Pdca

In the next three slides the inputs and outputs of SFL machine with the resources selected, a collection of lean management material, are presented:

Chapter-25-Lean-Management_2017_Total-Quality-Management.pdf

25.3 DEFINITIONS ON LEAN MANAGEMENT

Q: What lean manufacturing or lean production , " lean is?

A: a systematic method for the elimination of waste (" Muda ") within a manufacturing system

S: Lean manufacturing or lean production, often simply "lean," is a systematic method for the elimination of waste ("Muda") within a manufacturing system.

R: 0.0

Chapter-25-Lean-Management_2017_Total-Quality-Management.pdf

Q: How the Lean Enterprise is defined?

A: as an organization that creates customer value through a process that systematically minimizes all forms of waste

S: http://www.epplans.com The Lean Enterprise is defined as an organization that creates customer value through a process that systematically minimizes all forms of waste.

R: 0.0

Chapter-25-Lean-Management_2017_Total-Quality-Management.pdf

Q: In which conditions lean is about doing more with less?

A: while giving customers what they want

S: Lean is about doing more with less: less time, inventory, space, people, and money, while giving customers what they want.

R: 0.0

Chapter-Two-The-Lean-TPM-Master-Plan_2015_Lean-TPM-Second-Edition-.pdf

2.2 THE ORIGINS OF LEAN THINKING

Q: When a pull system is used?

A: when it is not possible to satisfy a customer instantly

S: When it is not possible to satisfy a customer instantly then a pull system is used.

R: 0.0

Chapter-Two-The-Lean-TPM-Master-Plan_2015_Lean-TPM-Second-Edition-.pdf

Q: How the amount of value - adding time improves as materials do not sit in buffers or contain defects?

A: by concentrating upon the elimination of waste

S: By concentrating upon the elimination of waste, the amount of value-adding time improves as materials do not sit in buffers or contain defects.

R: 0.0

Chapter-Two-The-Lean-TPM-Master-Plan_2015_Lean-TPM-Second-Edition-.pdf

Q: What TPM is?

A: involving everyone from shop floor to boardroom a team - based and freshly focussed tool for success

S: Involving everyone from shop floor to boardroom, TPM is a team-based and freshly focussed tool for success'.

R: 0.0

Chapter-Two-The-Lean-TPM-Master-Plan_2015_Lean-TPM-Second-Edition-.pdf

Q: How flow performance improves?

A: as a result

S: As a result, flow performance improves and the cycle between paying for materials, conversion and sale of the materials is compressed to improve the operational and financial performance of the firm.

R: 0.0

Chapter-Two-The-Lean-TPM-Master-Plan_2015_Lean-TPM-Second-Edition-.pdf

Q: When Unnecessary Motion occurs?

Chapter-Two-The-Lean-TPM-Master-Plan_2015_Lean-TPM-Second-Edition-.pdf

Q: In which conditions that is process optimisation , a key part of the ' proactive maintainers ' role?

A: once breakdowns are brought under control

S: That is process optimisation, a key part of the 'proactive maintainers' role once breakdowns are brought under control.

R: 0.0

Zgz_Workshop_LeanFundamentals_v02.pdf

4. In-Station Quality - Jidoka

Q: How 5S system for organizing spaces work can be performed?

A: by eliminating all types of wastes

S: 5S System for organizing spaces so work can be performed efficiently, effectively, and safely, by eliminating all types of wastes.

R: 0.0

Dialnet-IntroductionOfLeanManufacturingPhilosophyByKaizenE-5680376.pdf

Q: What this reduce?

A: waste of value adding processes generating most significant findings with the efficiency of processes

S: This is the main goal of philosophy Lean Manufacturing, reduce waste of value adding processes, generating most significant findings with the efficiency of processes.

R: 0.0

Dialnet-IntroductionOfLeanManufacturingPhilosophyByKaizenE-5680376.pdf

5. FINAL CONSIDERATIONS

Q: How the method of process improvement through Kaizen events enable the consolidation of improvement continuous processes?

A: by creating an organizational culture that prey by optimizing and facilitating the work

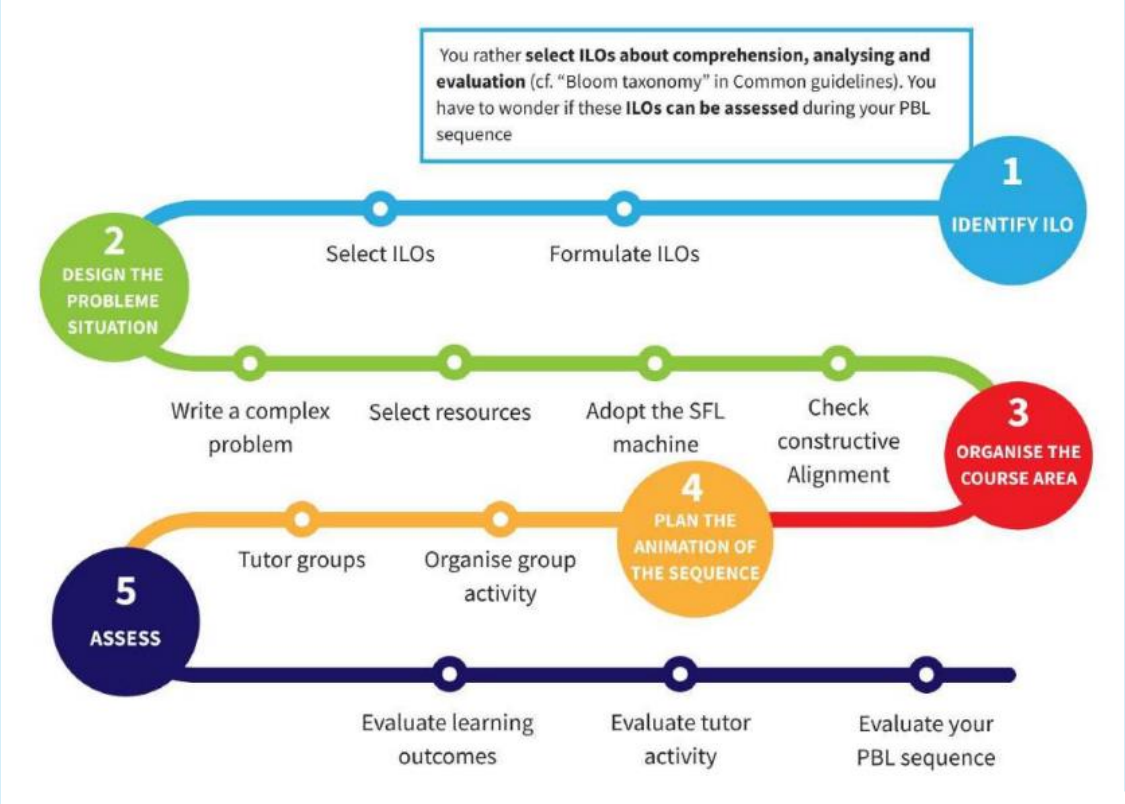
S: The method of process improvement through Kaizen events provides a position to act on various critical processes of the value chain in a short period of time, and consume little runtime and have a low budget implementation, enable the consolidation of improvement continuous processes, by creating an organizational culture that prey by optimizing and facilitating the work.

R: 0.0

03.

Activity Design

Problem based learning course design: scope



3.1.- Identify ILO

- The general objective of this practical workshop is to allow the students of the master's degree in mechanical engineering at the School of Engineering and Architecture at the University of Zaragoza to apply the concepts of production management, operations management and lean-continuous improvement in a practical workshop based on in the combination of the learning factory methodology with Problem Based Learning.

- For this reason, it has been determined that the main learning outcome is:

  Apply the knowledge learned during the sessions of the master program on lean management in the effective resolution of a complex organizational problem

3.1.- Identify ILO

- This general objective has several sub-objectives:.

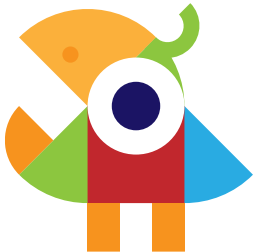
  ✓Identify the basic elements and indicators of a production process
  ✓Identify and categorize various production and demand problems
  ✓Determine the root cause of production problems
  ✓Apply knowledge of lean principles and practices to solve production problems.
  ✓Plan and implement solutions to production and demand problems
  ✓Evaluate the results of the application of solutions

3.2- Design the problem situation

3.2.1.- Write a complex problem

- **The root problem to be faced by students is to answer this question:**
  - How to meet truck consumer demand?

It is a complex problem that requires the resolution of various production sub-problems that allow the generation of a lean production line that provides the trucks at the time that the customer wants, with the design that he wants, with the lowest possible cost, with zero defects and generating zero waste. It is a classic problem of application of lean concepts.



3.2.2.- Design the problem situation

The problem is not presented in the traditional way in PBL, through a written proposal, but rather it is generated through the application of the learning factory methodology. In this case, an adaptation of the Flowcar game from https://leanshopping.com/ in which students have to play three iterative rounds of the game, until they meet the market demand. (approaching cycle time to tackt time) . Studenst “discover” the problem in an initially “full of them” factory

3.2.2.- Design the problem situation

Students are responsible for analyzing the initial situation of the production plant to define and determine the origins of production problems by establishing the root problem. It is a way that **motivates** the participants. It is an **open problem**, since there is no single solution. It is **complex,** since it needs at least three iterations to solve the problem. It is **consistent** with the content of the master since it allows students to apply multiple lean improvement techniques, and it is **cooperative**, it is necessary for students to work as a team. The challenge always seems to be hidden, Since the students always focus on the production problem and in almost all cases, they do not focus on the demand analysis. The tutor should prepare some clues to help the students discover what the root problem is, and how to adopt solutions to solve them.

The problem students have to solve it's a **Diagnosis-solution** one.

3.2.3.- Check constructive aligment:

- **We have used the checking complex problem quality table:**

Checking complex problem quality		Assessment
How to check : *G Good* *F Fair* *TBI to be improved*		
Problem Interest and motivation (PIM)		G
New problem	Will the students need to analyse and explore the situation before starting a solving process?	G
Problem relevant to Curriculum-	Will the students consider the PBL problem relies to their curriculum and to the ILOs of their training programme?	G
Context-induced motivation	Will the context be a source of motivation and interest?	G
Contextualisation details	Is the context correctly described? Are there enough details to immerge?	G
Real-world connected	Is the problem related to real professional problematics?	G
Learning process (LP)		
Relevant to ILOs	Has the problem been defined to reach the ILOs?	G
Relevant to pre-existing knowledge	Will students need to recall their existing knowledge as an input in their method?	G
Teamwork	Does the problem need a group work to be solved?	G
Several solutions	Is the complex problem open-ended?	
Feasibility conditions (FC)		
Difficulty	Is the problem difficult enough for learning? Isn't the problem too difficult for solving?	F
Scheduling	Is the schedule of sessions suitable for handling the PBL problem?	F

04.

Implementation of the Activity

4.1.- The activity program is this:

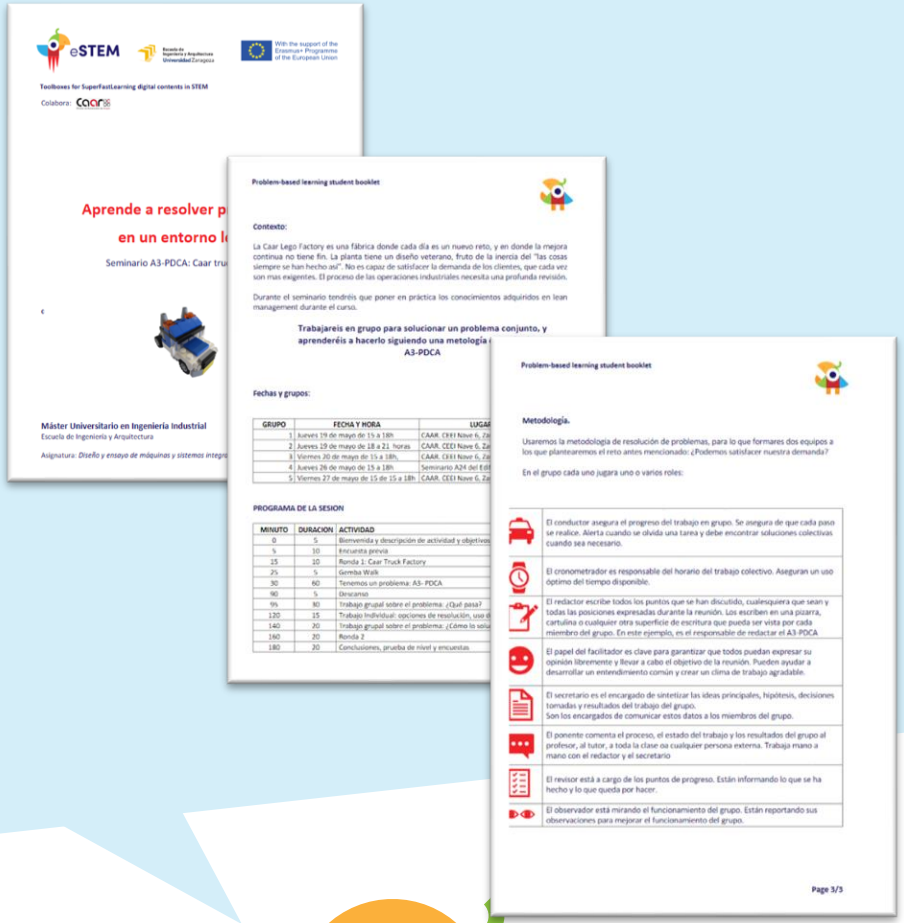
1. Round 1: Hands on Car Truck Factory
2. Gemba Walk
3. A tool: A3-PDCA
4. Work Group 1: What happend?
5. Individual work
6. Work Group 2: How do we solve it?
7. Round 2: factory improves
8. Conclusions, level test and surveys

4.1.- Implementation: Before the activity:

Before the activity, students are sent the student's booklet (DOC 1 SPANISH BOOKLET.pdf), where participants receive basic information of the session, and the main question: The Caar Lego Factory is a factory where every day is a new challenge, and where continuous improvement has no end.

The plant has a veteran design, the result of the inertia of "..things have always been done that way." It is not capable of satisfying customer demand, which is increasingly they are more demanding.

The process of industrial operations needs a deep review.

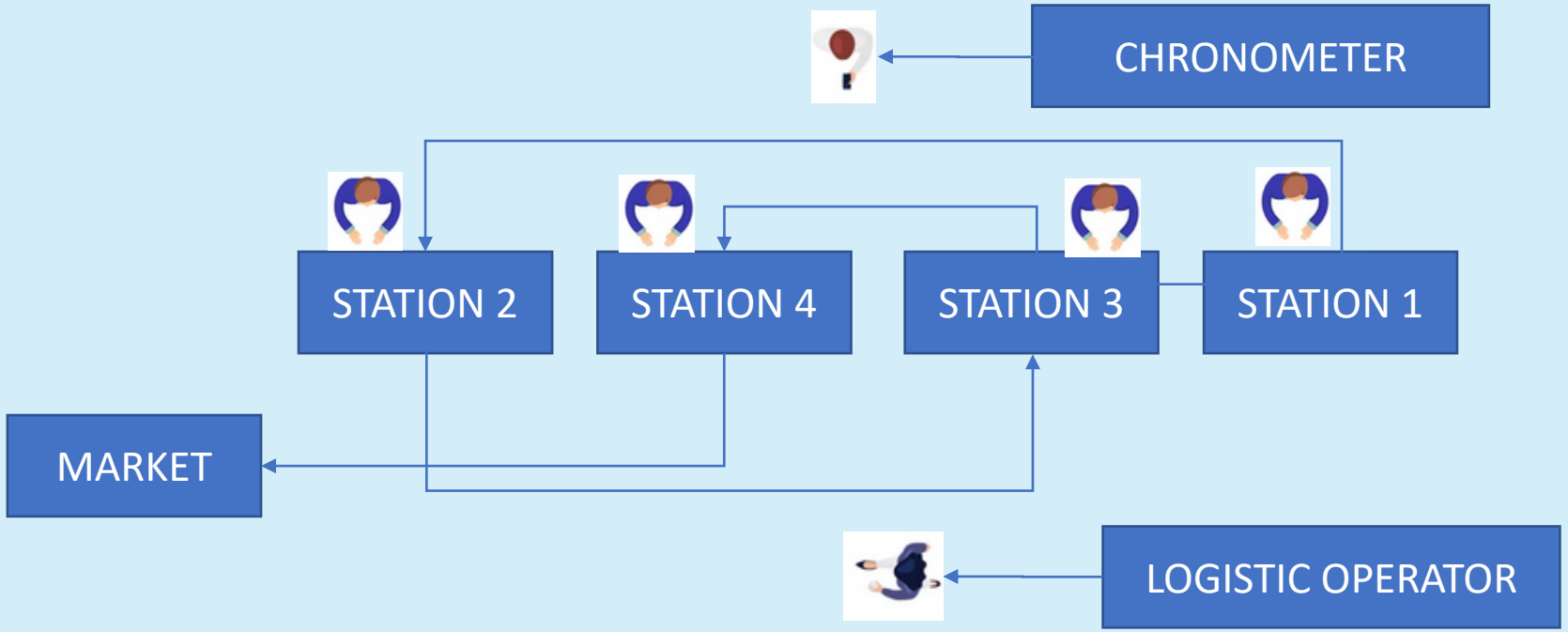


4.2.- Round 1: Things must go on

- **Just five minutes for a people introduction, other organissues, and some general information (part one of DOC 2 Students presentación.pdf)the group is splited in two teams to just start manufacturing trucks. This creates a little Chaos due to, the haste of the beginning of manufacturing, the very short information provided, the lack of experience and, to a certain extent, the surprise that the students receive, expecting a more conventional class.**

- **In this first roud, they have 5 minutes to manufacture trucks in 4 stations, in 3 lot production orders, of two models: the tractor and the van. The layout is given (an is very bad design) Some students mount pieces, and other are in logistics task, and time measuring responsibilities (time measuring is basic, as we are focus on the relation between cycle and takt time) In the next slides you can find a plant layout, the cards with tasks to be done by each station, and a general view of this round seconds before the beginning.**

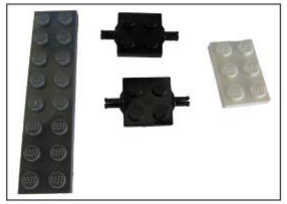
- **When station 4 finishes a lot, it is taken to the market, where the game facilitator checks if the products are quality compliant, and if there is demand for them. Then there is a sale**


CHRONOMETER
STATION 2
STATION 4
STATION 3
STATION 1
MARKET
LOGISTIC OPERATOR

STATION 1	STATION 2	STATION 3	STATION 4

Instrucción de trabajo para la operación nº 1

Para esta operación necesitará la siguiente materia prima:



Descripción del proceso

Descripción	Ilustración
Ensamble los cuatro ladrillos como se muestran en el lado derecho	

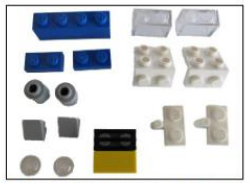
Instrucción de trabajo para la operación nº 2

Para esta operación necesitará la siguiente materia prima:

Descripción del proceso

Descripción	Ilustración
Agregue los cuatro ladrillos de color gris claro y el ladrillo largo de color gris oscuro como el siguiente	
Termine la estructura del medio, como se muestra, con 3 ladrillos blancos	
Agregue el ladrillo de color negro uniforme y el blanco uniforme	

Instrucción de trabajo para la operación nº 3



Para esta operación necesitará la siguiente materia prima:

Descripción del proceso

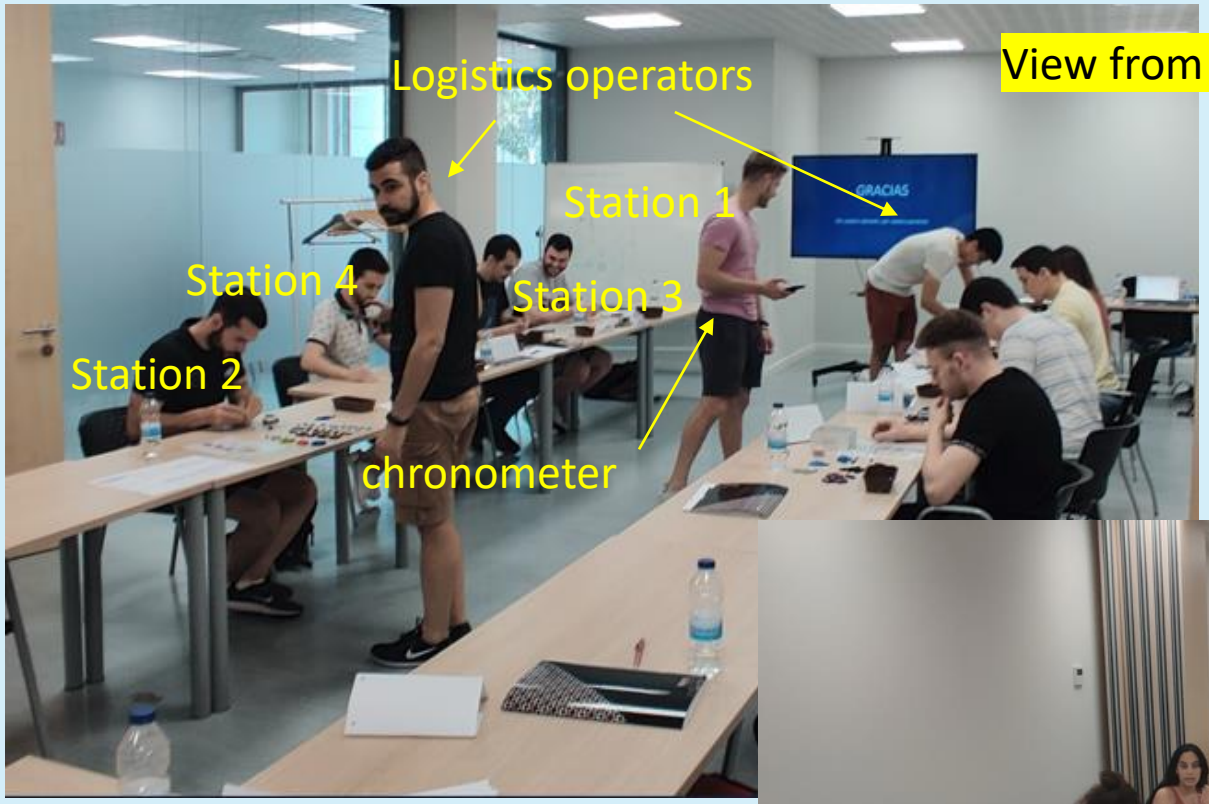
Descripción	Ilustración
Agregue los dos parachoques frontales y espejos retrovisores laterales y los dos ladrillos azules.	
Agregue refrigerante, dos faros intensos y dos parachoques grises en la parte frontal del vehículo.	
Agregue los dos parabrisas, una cabina azul y dos tubos de escape grises.	

Instrucción de trabajo para la operación nº 4

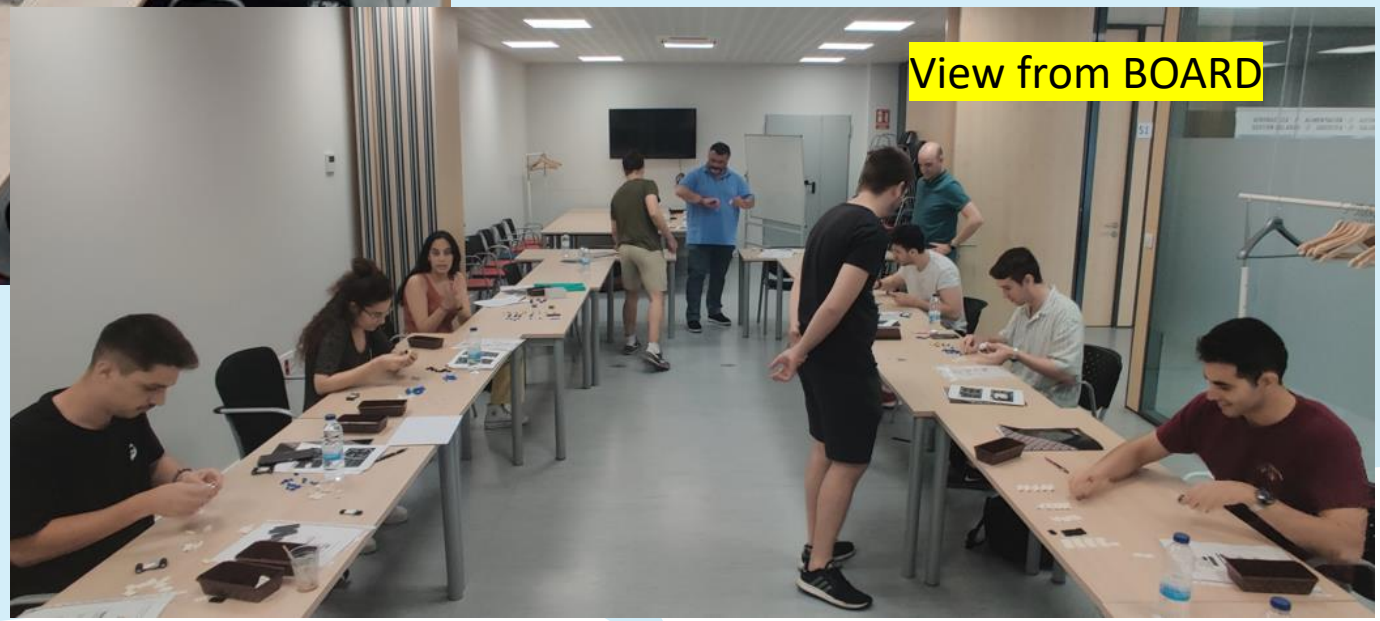
Para esta operación necesitará la siguiente materia prima:

Descripción del proceso

Descripción	Ilustración
Agregue el techo negro y cuatro spoilers azules, el capó y las cuatro ruedas.	
Ensamble el resto del techo con luces, dos tubos de escape y, finalmente, la barra trasera de conexión para el remolque.	



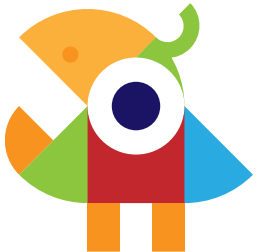
View from MARKET



View from BOARD

4.3.- The discussion cycle

2. • “Gemba Walk”
3. • A tool: A3-PDCA
4. • Work Group 1: What happend?
5. • Individual work
6. • Work Group 2: How do we solve it?

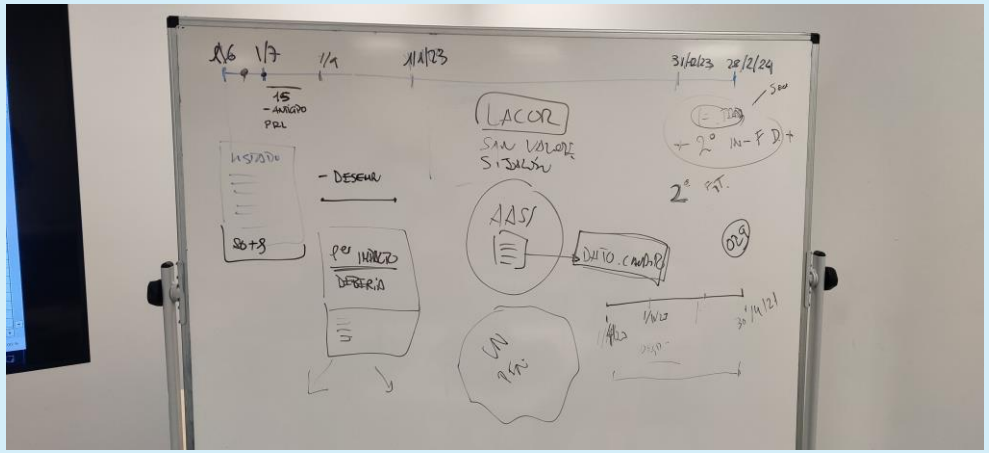


4.3.- The discussion cycle

- **Once the students finish the first round, they first take a walk through the plant (a gemba walk in lean terminology) so they can see what the final result is. After this round, there is a presentation of lean principles and the A3-PDCA problem solving methodology. They are encouraged to deepen the analysis with additional tools such as the 5Whys, the igikawa diagram and root cause analysis. The instructor leads a discussion to clearly define the concepts of cycle time and takt time, station balancing, push-pull**

2. The discussion cycle

- **Once the students finish the first round, they first take a walk through the plant (a gemba walk in lean terminology) so they can see what the final result is. After this round, there is a presentation of lean principles and the A3-PDCA problem solving methodology. They are encouraged to deepen the analysis with additional tools such as the 5 Whys, the igikawa diagram and root cause analysis.**

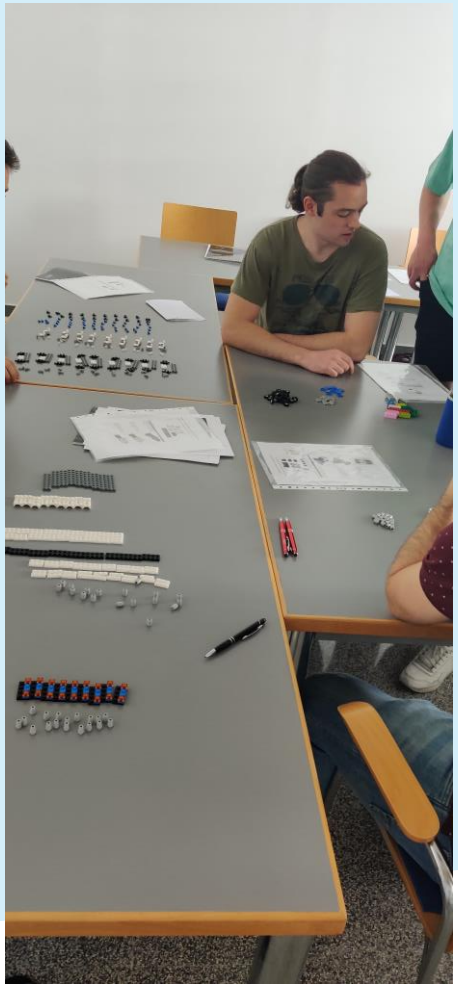


- **The instructor leads a discussion to clearly define the concepts of cycle time and takt time, station balancing, push-pull manufacturing, one piece flow, and other lean concepts.**

4.3.- The discussion cycle

Students are given time to:

- **Carry out an analysis of what has happened in the group**
- **Reflect individually on how to solve the problem, using the articles and material provided**
- **Meet again to propose solutions to problems. The instructor in this second round, and depending on the total number of rounds that can be played in relation to the available time, defines which elements of the line can be changed and which cannot (position of the tables, number of stations, design of the line, number and tasks of each station, etc)**

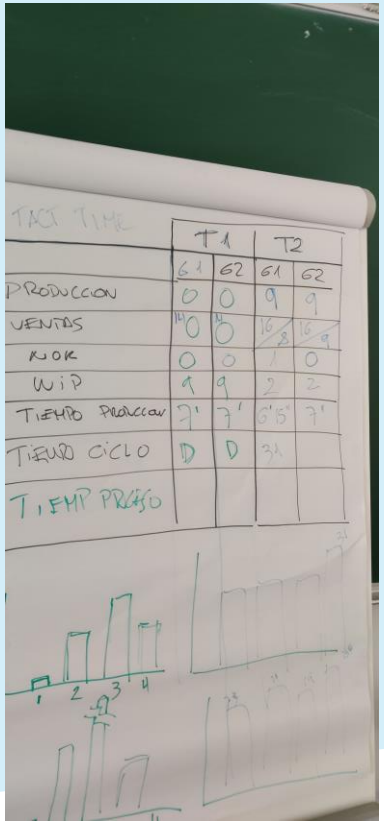


4.3.- The discussion cycle: KPI`s Pannel

- **During the game phase, we describe with the students which indicators will allow us to improve, that is, measure the problem in the first round, and see how the indicators improve.**

- **In this edition of the game, the quantity produced, sales, quality non-conformities (NOK), work in progress (WIP), cycle time and process time are measured for each team. In addition, they are encouraged to calculate the takt time by analyzing the demand they have had during the five minutes of the shift.**

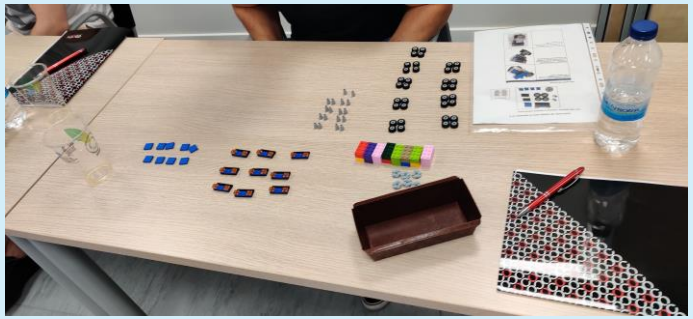
- **This methodology allows them to establish the dimension of the problem and how their decisions improve the indicators.**

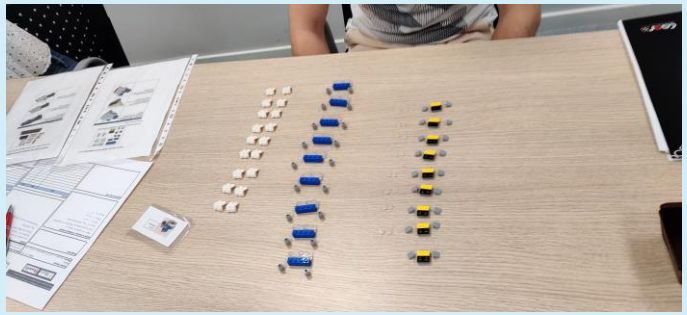


4.4.- Round 2: improves

Afterwards, the groups can start to improve the factory situation by applying LM and quality tools, and implement them. They are able to simulate the factory each time they change the layout to observe the effect that it causes. Thus, the factory optimization should be an iterative process, starting with the simpler measures and following the continuous improvement philosophy.

The students redesign the stations and the layout, reassign tasks, and in some cases advance solutions such as production in U, or the introduction of Kanban.





4.4.- Round 2: improves

The turn is played with the changes, and the results are measured again. The facilitator can introduce changes in the market:

- **reducing the takt time**

- **- Introducing models that do not exist in the lawsuit**

This reinforces the concept that there is no end to continuous improvement, and that the market changes.

05.

Results and Conclusions

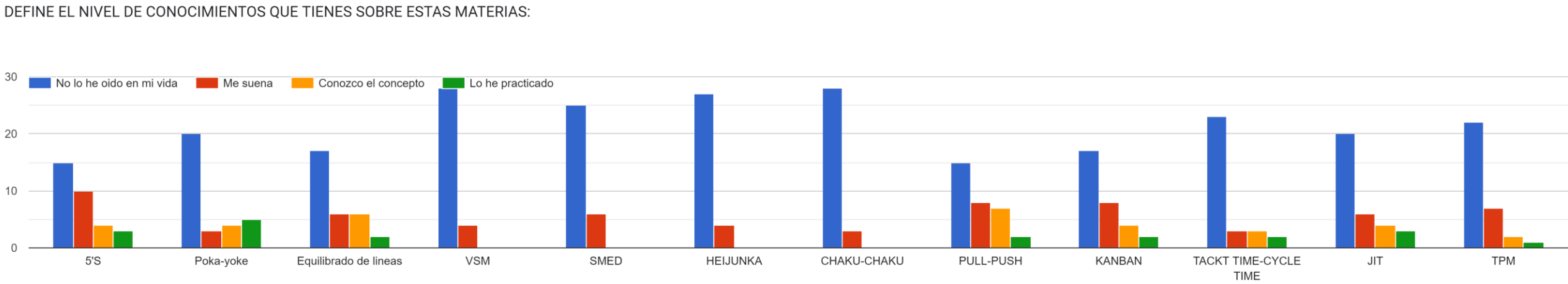
5.1.- Results

The evaluation and assessment of the methodology was carried out in three phases:

- **A previous questionnaire was carried out to assess the level of knowledge of the participants about various lean concepts and tools. The objective was to have an assessment of the general knowledge of the group.**
- **The students were evaluated with two elements:**
  - A level test of 10 questions was carried out to determine the degree of assimilation of the concepts of the A3-PDCA methodology that the students had acquired.
  - The A3-PDCA that the students carried out to solve the proposed main problem was assessed.
- **The methodology was evaluated using a rating scale that allows knowing aspects such as motivation, user experience and learning. This questionnaire has been prepared in the context of the research project that the speaker is developing in collaboration with the School of Engineering and Architecture of the University of Zaragoza, and is based on models for assessing the training of authors such as Kirkpatrick D., Gresse von Wangenheim C, Savi R, Borgatt A, and the use of the Likert scale.**

5.1.- Results: Level Questionnaire

- **This is the result of the students' level of knowledge of the Lean elements questionnaire. As can be seen, the blue color predominates, which indicates that the student has a total ignorance of the methodology**



5.1.- Results: Students evaluation and Questionnaire

- **Taking into account the results of the exams, the subjective evaluation of the participation of the students by the facilitators, and the evaluation of the practical work, the average marks achieved by the students are these:**

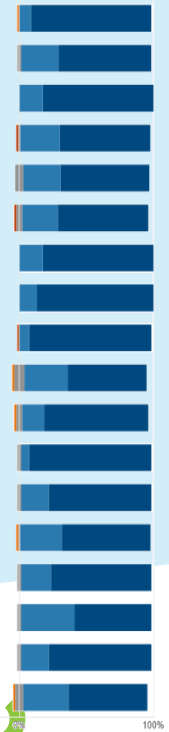
PARTICIPATION	EXAMS	PRACTICAL WORK	TOTAL
7,05	0,44	0,90	**8,39**

- **All aspects related to participation in the activity and practical work have been significantly overweighted, due to the nature and content of this activity, which is eminently practical and complementary to the main program.**

5.1.- Results: Methology evaluation

- **The graph shows the answers given by the students to the questionnaire on the evaluation of the methodology. The questionnaire is anonymous and is answered from the mobile phone. As can be seen, (+2 = dark blue) the students value all aspects of the game very positively, highlighting...**

The game design is attractive
The content of the game is connected to other knowledge that I already had and have studied in the course
It is easy to understand the game and start using it as study material
During the game, I realized that I was learning
I know that I will have the opportunity to put into practice the things I learned playing this game.
During the game, I forgot about my day to day
I have been able to interact with others during the game
I have fun with my classmates
The game promotes moments of cooperation and/or competition between players
This game is a proper challenge for me, the tasks are not too easy and not too difficult
The game progresses at a suitable pace and does not become monotonous: it offers new obstacles, situations or variations on your tasks
I have fun with the game
I would recommend this game to my colleagues
I have achieved the goals of the game by applying my knowledge
I would like to play this game again
How much do you think the game contributed to your learning in this course?
How efficient was the game for your learning, compared to other activities in the course?
Do you think that the experience with the game will contribute to your professional performance in practice?

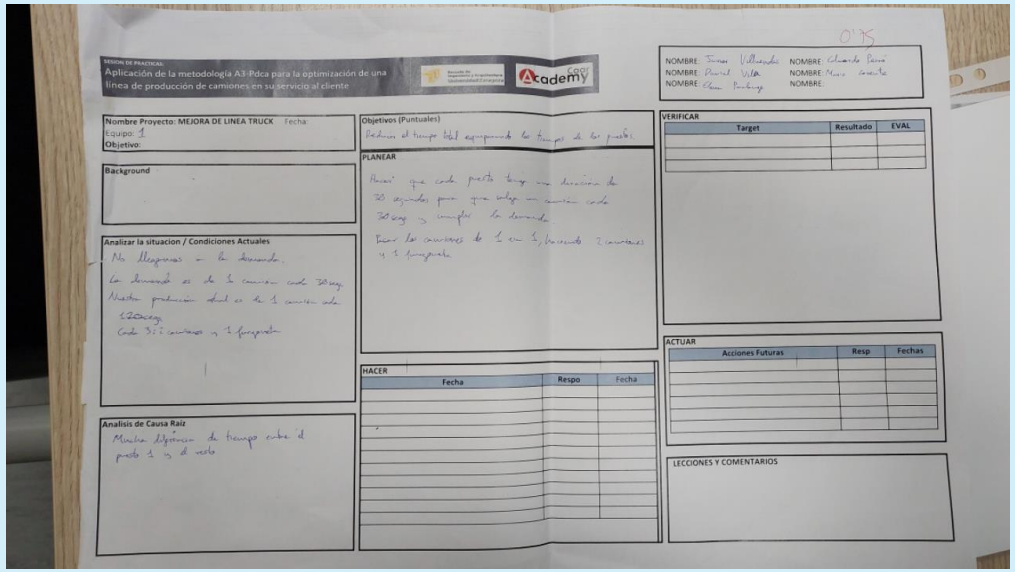


5.2.- Conclusions

During the conclusions, the concepts of:

- **Customer orientation**
- **continuous improvement**
- **Balanced production, one piece flow**
- **KPI's and OEE**

And the working method with the A3-PDCA is also reviewed for each team

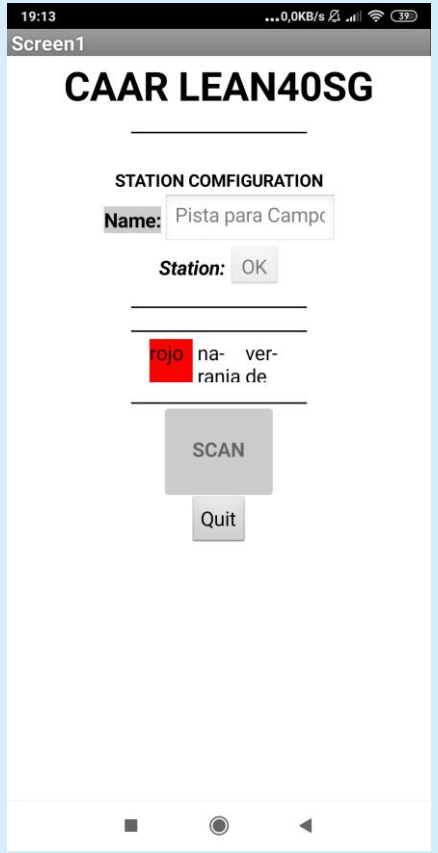


5.2.- Conclusions

The game can be played for two to three turns, more assuming, in our experience, too many turns.

The game allows introducing elements as varied as logistical problems, subcontracting, delving into the elements of the main productive KPI that is OEE, and even using industry 4.0 elements such as replicating a MES / HMI on student phones for production control. , explaining its design and programming.

For this, however, a duration much longer than the 3.5 hours of this example is required.



5.1.- Conclusions

- **The game is evaluated very positively by the students since it allows them to put into practice what they have seen in the classroom during the master's sessions.**
- **The methodology is attractive and well valued, as explained in the previous section.**
- **ESTEM molding can help in this type of activity by giving certain guidelines to the facilitator or teacher. It brings ideas when teacher comes to guiding the key aspects that students must assess in order to face the problem and propose solutions.**

WORK SHOP ORGANISATION:

Aragon mobility and automotive cluster

ESTEM PROJECT CONSORTIUM:

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