DEVELOPING ENGINEERING COMPETENCES APPLYING THE FACTORY LEARNING METHODOLOGY UNDER THE NEW TEC21 EDUCATIONAL MODEL

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Abstract

The development of technology has forced us to change many different aspects of our lives, including the learning process. The fundamental objective of the Universities was to deliver the knowledge to the students, but nowadays, the availability of knowledge is greater with the new digital technologies. The new Tec21 Educational Model establishes the Challenge Based Learning (CBL) as one the main pillars of its development. Here we report on the use of *Factory Learning* as part of the CBL process. The *Factory Learning* methodology focuses on developing different skills and abilities in the student, giving them a challenge to solve. The teacher in this methodology is a mentor that leads the student to develop the skills as he acquires knowledge.

Keywords: Competences development, Tec21, Educational Innovation, Challenge based and long-life learning.

1 INTRODUCTION

The function on a Universities on the past century was to gather and transmit the knowledge. This task has changed with the use of technology. Now a days there are different ways the knowledge can be obtained, from a simple search on the web, an on-line course, Massive Open Online Courses (MOOC) and many other digital media that can be found on the web. Therefore, it is important to reflect on the actual purpose of the universities. To answer this question, it must be taken into account that the educational process has evolved over the years. The needs of the new generations are very different from those of the previous decades. That is the reason why teaching techniques have changed over the years, but recently this change requires a shorter time to improve than in previous decades. New techniques such as the case method, problem-based learning (PBL), challenge-based learning (CBL), the inverted (Flipped) classroom and many other new teaching techniques are now available to be applied.

The universities have taken measures to keep up to date, so in the 90s the case method was developed [1, 2, 3, 4]. In that year, Harvard noted that the education process requires improvement, and thus develop the case method to improve the learning process. The case method consists of a previously resolved case that is applied to solve some problems. Then, the case is presented to the student and the objective is for the instructor to take the student to the presented solution. This was an important advance at that time because it was one of the first attempts to change the dynamics of a class. Another attempt to improve the educational process was the PBL, in which, instead of giving a face-to-face class, a problem that requires the application of knowledge and concepts to solve it, is analysed. In addition, there is another change in the educational process, but the evaluation is generally about the retention of the concepts and the practical use of the knowledge acquired. Therefore, for evaluation of skill is not certainly the best approach.

According to the QS Top Universities 2019 rankings the Instituto Tecnológico de Estudios Superiores de Monterrey (ITESM) is ranked as the second best university in Mexico and the number 5 in the Latin-American University Rankings. With a high research output, ITESM has been rated with five QS stars, achieving full marks in employability among other categories [5]. A key role in this achievement has been played by the constant implementation of new education strategies. One of the main goals of the ITESM 2020 strategic plan is to promote the successful incorporation of graduates into professional life [6], developing leaders for major business and organizations in the country and abroad, not overlooking an entrepreneurial spirit and a humanistic outlook. To achieve this goal, the ITESM recently launched the Tec21 Educational Model [7]. It is a flexible model in its curriculum that

promotes student participation in challenging and interactive learning experiences. In this model, elements related to educational spaces and state-of-the-art classrooms with a high degree of interaction, converge with the skilful use of technology as well as the contribution of highly skilled, innovative and well-prepared teachers are involved. This model bases its success on improving competitiveness by boosting skills and developing the skills required in different professional fields. One of the central areas of Tec21 is to address the student's challenges to develop disciplinary and interdisciplinary skills.

A concept adopted at the Canadian university MacMaster is *Factory Learning* [8, 9]. The implementation of this didactic technique requires a laboratory equipped with different components and the student must learn to solve a problem with all the resources at his disposal. It is a mix between PBL and CBL where the teacher designs activities to solve and guide the students without giving them all the knowledge or their ideas to solve the problem.

In this manuscript, we report on the implementation of the *Factory Learning* technique in an automatic control laboratory as part of the CBL techniques useful for the implementation for the Tec21 model. The different activities to carry out the execution are presented and documented for their replica.

2 EXPERIMENTAL SETTINGS

2.1 The Factory Learning concept

Factory learning is a didactic technique in which the student is the main actor and the function of the teacher is to be a mentor and to give tutoring all throughout the course. In this methodology, a challenge to be solved over a period of time is chosen for a student and he must be self-sufficient to solve this challenge. In the process, the student develops the proposed competences and must acquire the required knowledge. The teacher in this type of situation would only be a client who would demand the highest quality for the product and would ask the students to improve their skills and abilities. In addition, in the case of engineering students, an adequate and equipped laboratory is needed to give the student the space and resources to solve the proposed challenge. The concept of *Factory Learning* is depicted in **Figure 1**. It is called *Factory Learning* because the challenge will help the student to create the skills and knowledge that will help him to be introduced into the working life.

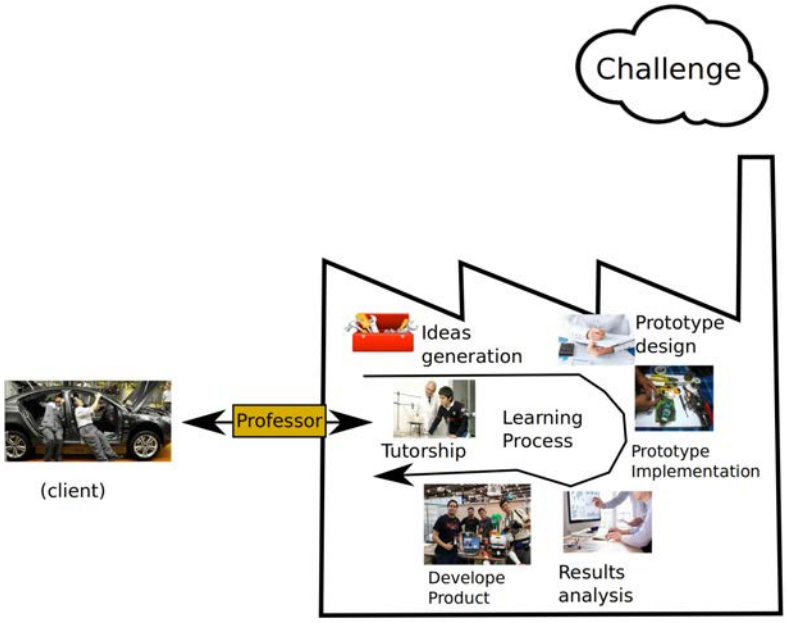


Figure 1. Factory learning concept.

The *Factory Learning* methodology is shown in **Figure 2.** It consists of 3 stages; Previous, Implementation and Conclusion stages of the learning process. The first stage includes the design of the challenge, the length of this period will depend on the skills and knowledge that the student must obtain during the activities. The equipment, tools and physical spaces are critical for the student to have a wide variety of options to choose the right one. Very importantly, this should focus on an

interesting topic to study. The process is a cycle that must be followed according to the previous design of the challenge. It is important to control how students work on the challenge and give constructive criticism to improve the research activities and give proper advice throughout the development of the contents. This cycle must be repeated every week or day according to the selected time period. In the final stage is the conclusion of the challenge, so there must be an assessment of the level of competences the student achieves, and the knowledge acquired by him. Normally, this is carried out using previously designed rubrics. This closes the *Factory Learning* process and allows knowing the level of progress that the student has achieved during this methodology. It is important to monitor how students work on the challenge and give constructive criticism to improve the experimental designing. This cycle must be repeated every week or daily according to the selected time of implementation.

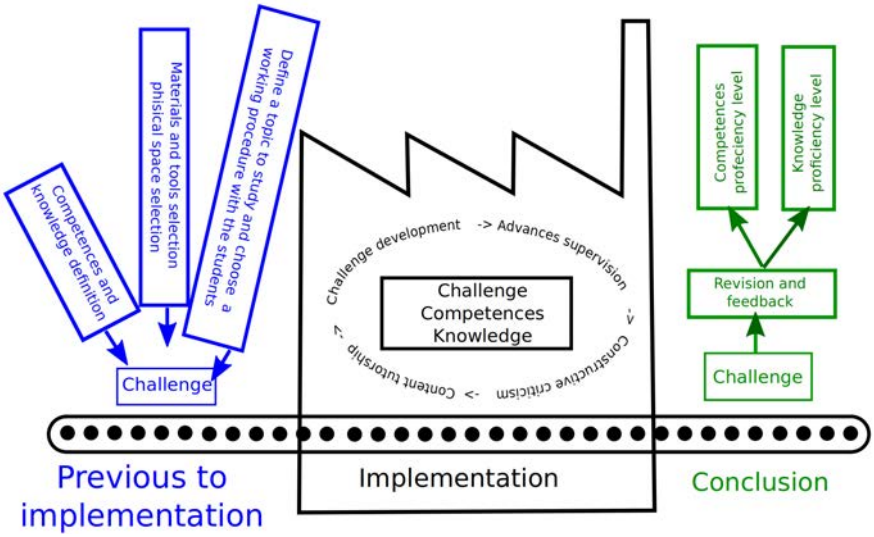


Figure 2. Factory learning methodology.

3 RESULTS AND DISCUSSION

3.1 The Factory Learning concept

In this case, the challenge was the same for the 15 students divided into five teams of three members each. All the students were from one before the last semester of the Mechatronics Engineering Bsc. Program. The challenge was to make a food delivery system with an automatic control (**Figure 3**). The students also had a kit of different components (tools, accessories, electronic components) that would be useful in the process of solving the challenge (**Figure 4 and 5)**. A weekly program plan was made to track progress and supervise the work, and to verify progress, students created a research record to register their progress.

The implementation was a little bit complicated due to the different dynamics of the laboratory. The students adapted to this new process and delivered a functional prototype on time. At the evaluation, the student values the many different aspects involved in the process, such as the planning process that played a key role in the development of a project, and the importance of focusing on a particular topic.

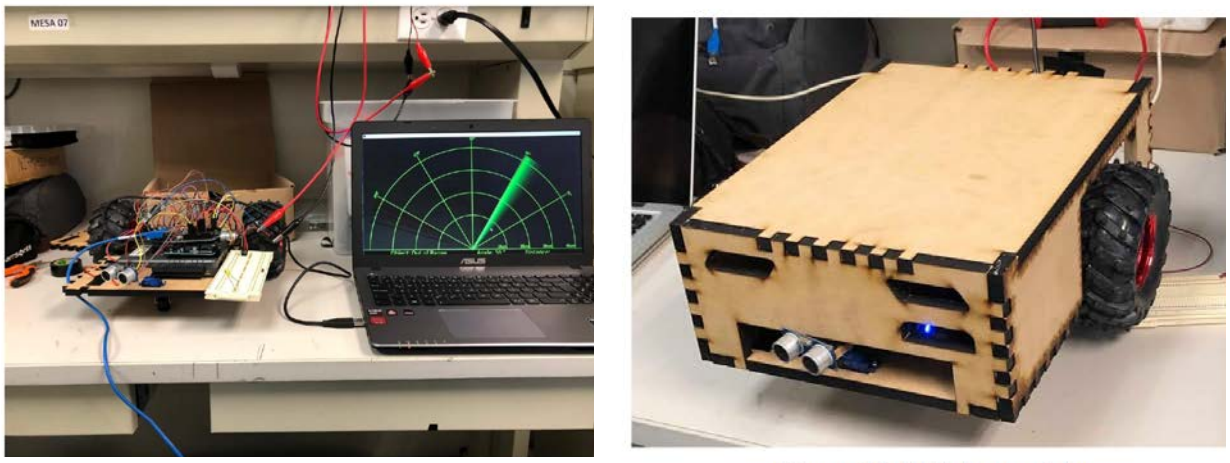
To evaluate the students acquired competences we used: the production of an evidences portfolio, written reports, exams, presentation with external examiners among many others. Specific rubrics to measure competences were also designed. The course was divided in three terms with one competencies evaluation each.

It was clear that this active learning technique allowed the student to obtain deeper and greater knowledge and experiences that will be useful to build a solid long-term learning. Some disadvantages should be considered to improve this factory learning. For example, students are not completely ready to learn from a blank project, so it is important to provide more ideas as a starting point to guide the student in the first steps. Another thing that may be improved are the milestones, taking into account

that students must pay attention to this period of time when they must deliver a significant progress of their project.

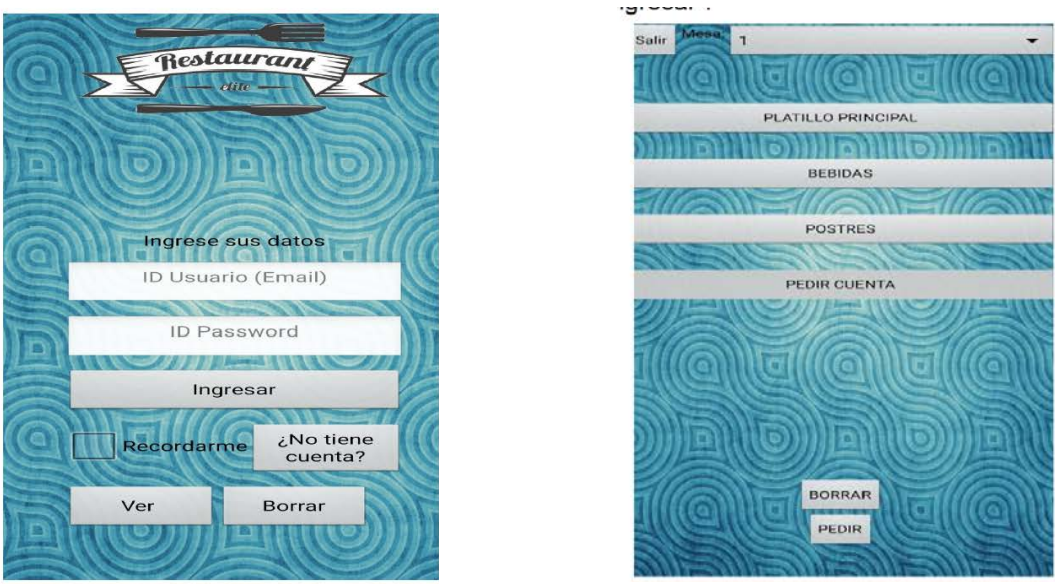
The student's grades were clearly higher in those students that were trained in the Factory Learning than those that had the traditional face-to-face course. This was probably because the students who applied the concepts to a practical solution demonstrated a better command of the disciplinary competences, such as mathematical analysis, design and practical implementations that are not fully developed in a traditional class. Therefore, if the student is focused on solving a tangible challenge, creativity and many other latent abilities are awakened to solve the challenge, improving the learning experience.

When interviewing, some students considered the project management and the planning process as equally valuable, concluding that without these two elements, knowledge is not significant if the project plan is not ready on time. Another aspect that students commented was that, for unknown projects, it is important to divide the task considering an analysis of strengths and weaknesses to choose the best team member to perform a specific task. This allows the student to perform a more natural teamwork and consider the abilities of each member to improve the development of the project. It is very interesting that one skill that was strongly developed was the self-learning ability as the search for updated literature was key to solve the challenges.



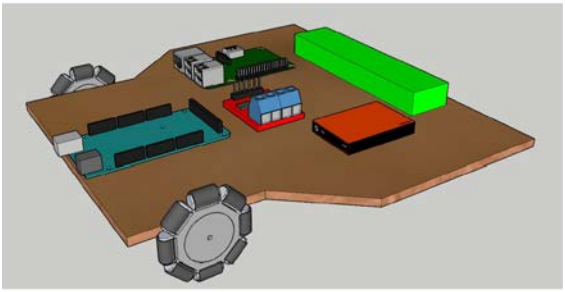
a) Evaluation of the radar system *b) Final prototype*

Figure 3. *Practical prototype testing and final design*

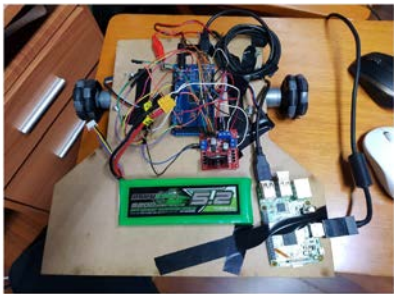


a) Principal menu *b) Delivery menu*

Figure 4. *App design for the costumer*



a) Simulation design



b) Experimental design

***Figures 5**. Simulation and experimental design*

The Internet and the development of online learning systems are two reasons why, in the last years, the educational model focused the development of competences emerged [JS1]. This type of teaching is not only based on concepts and knowledge acquired; It also focuses on the development of skills. Competencies are a combination of skills and abilities that allow the student to be prepared for certain challenging problems [AE1].

3.2 Educational process, the rapid evolution

A classic face-to-face class is where a teacher explains the concepts using different materials to transmit concepts, but this kind of class is not appropriated for the new generations. The *Factory Learning* technique may be applied in the absence of internet or digital media and to obtain technical information was complicated to obtain.

In the last decades of the past century, the need for new didactic techniques has been imperative. As a result, the case model, the CBL and PBL techniques have been developed to prepare the students to face the professional environment. The accelerated used of the technology, especially the Internet, has changed education as it was previously known. Due to this reason the competencies education model has emerge, allowing the student to develop skills and abilities that will allow them to overcome challenges they have not been previously exposed to.

Based on the competencies model a series of didactic strategies have emerged, e.g. Flipped classroom, gamification, and *Factory Learning* among many others. All these methods are designed to develop competencies in the student that will give them a long-life learning. But as the labour market, new technologies and tools evolve so rapidly, very probable, those competencies will be out of date very soon and new ones must be learnt.

4 CONCLUSIONS

The Factory Learning Technique is a new paradigm in educational models, which combined with the Tec 21 model, can significantly improve the learning process. This type of activities are the future to solve challenges, which by definition are projects that have not yet been designed. Factory learning confronts an engineering student in a situation where they must evaluate and solve a multidisciplinary challenge. In this particular case, it implies all the knowledge that a mechatronics engineer must have, such as mechanical design, programming and automation. This type of challenge offers a difficult task that must be solved, and it is through this resolution that it is expected that the contents of the study subjects will be covered and learned.

One of the interesting results found in the implementation of Factory Learning in the automatic control laboratory is that the student can improve skills that have not been fully developed. In many cases, the students reconsidered the value of some subjects that they had already studied but that had not awakened in them much importance because they were isolated, without a multidisciplinary connection. In conclusion, if we use the learning factory under the Tec21 model, the student will have better training for working life and will be prepared to overcome different challenges of great difficulty..

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REFERENCES

[1] Gillham, B. (2001). Case Study Research Methods. London, New York: Continuum.

[2] Platt, J. (1992). Case study in American methodological thought. Current Sociology, 40, 17–48.

[3] Stake, R. (1998). “Case Studies” in: Norman Denzin & Yvonna Lincoln.

[4] Yin, R. (1984/1994). Case Study Research: Design and Methods. Thousand Oaks, London, New Delhi: Sage.

[5] MIT. QS Top Universities. [Online]. Available: https://www.topuniversities.com/universities/ instituto-tecnologico-y-de-estudios-superiores-de-monterrey [Accessed:13-Jan-2019]

[6] ITESM. Strategic Plan 2020. [Online]. Available: http://sitios.itesm.mx/webtools/ planestrategico2020/publico/EN/index.html [Accessed: 13-Jan-2019]

[7] Free document available at: https://observatory.itesm.mx/tec21/ accessed January 13, 2019.

[8] Elbestawi M., Centea D., Singh I., Wanyama T., SEPT Learning Factory for Industry 4.0 Education and Applied Procedia Manufacturing Volume 23, 2018, Pages 249-254

[9] Centea D., Elbestawi M., Singh I., Wanyama T. (2019) SEPT Learning Factory Framework. In: Auer M., Langmann R. (eds) Smart Industry & Smart Education. REV 2018. Lecture Notes in Networks and Systems, vol 47. Springer, Cham.

[10] Jhonstone S. M., Soares L. Principles for developing competency-based education programs Change: The Magazine of Higher Learning Volume 46, 2014, Issue 2

[11] Adelman C, Ewell P, Gaston P, Schneider C. Degree Qualifications Profile Lumina Foundation, NILOA (2014)

[12] Membrillo-Hernández, J, Ramírez-Cadena, MJ, Caballero-Valdés, C Ganem-Corvera, R, Bustamante-Bello, R, Benjamín-Ordoñez, A and Elizalde-Siller, H. (2018) Challenge Based Learning: The Case of Sustainable Development Engineering at the Tecnologico de Monterrey, Mexico City Campus. In: Auer M., Guralnick D., Simonics I. (eds) Teaching and Learning in a Digital World. ICL 2017. Advances in Intelligent Systems and Computing, vol 715. Springer, Cham. https://doi.org/10.1007/978-3-319-73210-7_103