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Challenge-Based Learning in Higher Education: Master's Degree in Logistics and Productive Operations Management from Mondragón University

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Abstract

Since 2022, Mondragon University has implemented Challenge-Based Learning (CBL) in the teaching and learning process of the Master's in Logistics and Productive Operations Management (MUDOLP) program. This article describes the application of CBL in four companies from different industrial sectors during the second semester of the 2022–2023 academic year. The challenges focused on reducing the variability of industrial processes through the implementation of a continuous improvement process and analysis following the Lean Six Sigma methodology in an environment of operational excellence. The results show that having a partner with experience in the CBL industry is important in increasing the complexity and uncertainty of the task, while also providing students with significant exposure to professional issues that need to be addressed.

Keywords: *challenge-based learning, higher education, Lean Six Sigma, operational excellence*

1. Introduction

In the new context of economic productivity, fresh paradigms prevail related to achieving maximum efficiency of productive resources in a sustainable way through the incorporation of new information and communication technologies (ICT). These developing conditions demand that organisations and industrial companies transform to be competitive, satisfy customer demands and remain in the marketplace. They also require that companies have personnel trained and prepared in the field of management with excellent advanced logistical and

productive operations skills who can guide their companies towards the transformations required by the new prevailing paradigms (Mangla et al., 2020). To prepare master's program students with the skills needed to work in the increasingly complex and diverse environments of higher-level industrial organisations, it is necessary to adopt appropriate pedagogical approaches (Helker et al., 2024). One strategy that may be relevant to this approach is Challenge-Based Learning (CBL) (Christersson et al., 2022). Since 2022, Mondragón University (MU) has implemented CBL in the teaching and learning process in the Master's program in Logistics and Productive Operations Management (MUDOLP). This paper examines its application during the second semester of the 2022–2023 academic year. In the aforementioned case, the students immersed themselves in challenges in four companies from different industrial sectors, focusing on the problem of reducing the variability of industrial processes. In each case, this was achieved through the implementation of a continuous improvement process following the Lean Six Sigma methodology in an environment of operational experience. These challenges were designed and agreed upon by the company staff and MU professors. In the experimental setup, the learning modules and contents were aligned with the objectives of both the company and the university. The challenges raised topics related to industrial operational excellence, such as the variability of industrial processes, lean production, continuous improvement models, sustainable production and people-centred production. Transversal skills, such as teamwork and communication, were also addressed. Teachers continuously monitor this process, focusing on analyzing students resilience to failure, problem solving, and how each student acquires content knowledge. The main difference between a problem controlled by a school and a completely uncertain problem created in an industrial plant is the degree of uncertainty about the solution to that problem (Chapel et al., 2021). Many factors were evident in our study. For example, cross-disciplinary skills such as teamwork, critical thinking, ethics, problem solving, planning ahead, and resilience have been observed (Chapel et al., 2021). Our results show that having an industry partner for CBL experience is important in increasing task complexity and uncertainty, and also helps significantly in helping students are exposed to real-world professional problems that need to be solved (Chapel et al., 2021). Consequently, skill development is consistently greater than learning delivered through traditional methods, as a theoretical teaching classes.

2. Challenge-Based Learning

CBL is an innovative learning strategy specifically designed by Apple's education team to develop and refine the skills engineering students need to succeed in today's world by collaborating with colleagues, professors, and experts in their fields to solve real-world problems (Apple Inc., 2012). Engineering educators encourage this active learning style as an appropriate way to develop critical thinking skills in engineering students (Membrillo-Hernández et al., 2021). As Helker et al. (2024) mentioned, CBL has become increasingly

popular in higher education as it aims to stimulate students to take initiative in their own learning, acquire and apply relevant knowledge to respond to the challenge. The CBL process begins with selecting a core idea and goes through the following steps to identify and solve the problem associated with that idea: physical problem; competition; instructional questions, activities, and resources; definition/solution article; action to implement the decision; result of evaluation; and sharing information with the world (e.g. publishing results) (Apple Inc., 2012; Mas et al., 2017).

3. Learning Experience

The following stages describe a learning experience in which CBL was used as an instructional strategy for the second semester of the 2022–2023 academic year of the MU master's degree program in logistical and productive operations (MUDOLP). This was based on the steps of the CBL strategy developed by Apple and takes into account that the reference topic of the second semester in the master's program is the design and application of continuous improvement strategies in the field of operational excellence. During this semester, the phases defined in our methodological process were supported with an improvement methodology based on the Six Sigma DMAIC (Define, Measure, Analyse, Improve and Control) (Thomas et al., 2017), which we call DMAIC-7P (Eguren, 2012) (Unzueta & Eguren, 2021). Templates in the form of a diary were developed to guide the teams through the different stages of the challenge to be addressed. The work route that appears in Figure 1 lays out the schedule, the different phases of the CBL and the phases of the reference process, which were interspersed throughout the semester that corresponded to the application of the Six Sigma methodology.

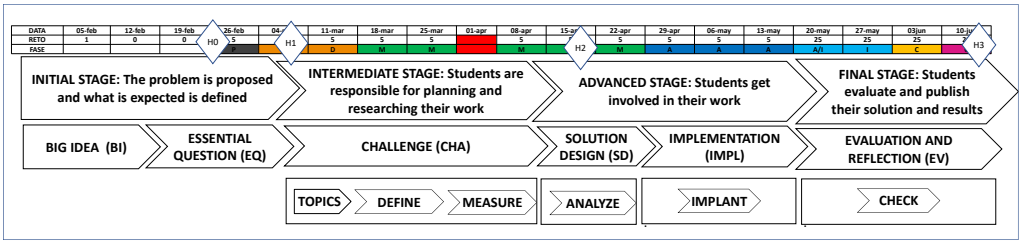

Figure 1: CBL methodology use

3.1. Team Formation

A total of 17 people enrolled in the MUDOLP master's program, of which four groups of four to five people were generated to address the challenge. The topic addressed in the session corresponds to how operational excellence can be achieved through the development of continuous improvement activities under the Lean Six Sigma philosophy in a real environment. To do this, each group tackled its challenge in a real company where internships were being carried out in alternation. Previously, the managers of the selected companies were contacted to

show them the work that would be addressed in the challenge and to get their agreement. Table1 shows the challenges identified by each group in their corresponding companies.

Table 1: Challenges identified for each group

	Team 1	**Team 3**	**Team 3**	**Team 4**
Type of company	Capital goods company	Automotive sector company	Capital goods company	Automotive sector company
Activity	Manufacturing of filtering installations	Rubber processing company	Sprayer manufacturing company	Carburetor manufacturing company
Challenge to address	Operational excellence in the painting area	Operational excellence of the injection machine tuning process	Operational excellence in the component storage area	Operational excellence in waste management

Each group was assigned a tutor to guide them in the process of addressing the challenge. Who has previously received training in the field of CBL and the Six Sigma methodology at the black belt level. The role of the expert tutor was to be a learning collaborator and to seek new knowledge together with the students, while at the same time molding habits and new ways of thinking. To do this, they were organised by monitoring through weekly meetings, where the activities to be carried out, the visits to be made to the companies and the evolution of the work carried out at all times were planned and monitored.

3.2. Initial Stage

At this stage, the problem to be addressed has been proposed, and what is expected has been defined. A general idea of solving the problem of operational excellence in industrial processes was introduced and the problem of reducing the variability of industrial processes was addressed using improvement models. Focus on operational excellence in each established area. After identifying the challenge to be addressed, the teams began to analyse the challenge topic and explore the questions that guided the formulation of a concrete and feasible strategy to solve the challenge (Apple Inc., 2012). The essential questions were related to the theoretical knowledge developed in parallel with the challenge that was being developed (van den Beemt et al., 2023). These correspond to the following thematic blocks and the questions below. Table 2 shows some guiding questions generated by the teams, as well as the blocks of developed content. As the challenges are developed in a real industrial environment, the complexity of the tasks addressed are significantly more complex and have greater uncertainty.

Table 2: Guiding generated by the teams for each topic

Topic	Essential questions
Analysis of Process Variability	How can I reduce the variability of an industrial process using Lean Six Sigma techniques?
CI Models	What elements and factors have an influence when approaching a CI project?
Sustainable Production	What aspects of the sustainability of industrial processes must be taken into account for operational excellence?
People-Centred Company	How are people managed and organised?
Lean Production	What tools or techniques can I use to eliminate or reduce production waste?

3.3. Intermedial Stage

In this first stage, the challenge to be addressed has been specified, starting from the guiding questions identified in the previous phase, and the necessary activities and resources have been used and developed for each thematic block to describe the problem to be addressed. The steps of the DMAIC-7F (Eguren, 2012) methodology have been used as guiding support. In this section, the define and measure phases will be addressed, in which all the contents addressed by each thematic block included in the challenge will be incorporated.

3.4. Advanced Stage

This stage corresponds to the design and implementation of the solution. To do this, first, we have designed a thoughtful, concrete and clearly articulated solution that can be implemented in the local community. As support, the analysis phase of the DMAIC-7F methodology will be addressed. Next, we proceeded to address the solution implementation phase. For this purpose, an implementation plan was designed and addressed, depending on time and resources. Table 3 shows the improvements identified by each group.

Table 3: Improvements identified by each group

Team 1	Team 2	Team 3	Team 4
Implementation of the 5S tool	Reduce injection machine change time	Redefine component reference locations	Improved waste cart locations
Design of a procedure for changing the paint reference	Reduction of Lead Time of references that go through the oiling process	Incorporate solar panels	Cart dump lift system
Change in the Paint Layout	Defect reduction	Use recycled material in plastic packaging	Collaborative transportation robot
Design and implementation of a Kanban board		Calculate company's carbon footprint	Reduction of non-returnable referrals
		Carry out the Lay-Out study to minimise movements	Indicator of number of people in waste management
		Get people to be an active part of improvement teams	Logistics train

3.5. Final Stage

At this stage, the students evaluated and published the results of the challenge addressed by each team. To do this, they have developed a technical report that includes the process followed and its results and have made a presentation to their colleagues and the managers of the companies where they have carried out the challenge. In the aforementioned presentations, the students reported progress, problems and achievements during the process. Overall, the students admitted that the project required a lot of work, but even more so, they appreciated the bonds that developed between teammates during this intense work. They also noted that they learned how to communicate better with each other to move things forward (Apple Inc., 2012). This experience with CBL not only provided team members with knowledge on a topic relevant to their careers but also gave them a method to rationally approach a problem and helped them develop interpersonal skills to successfully work on a team (Apple Inc., 2012). Also, at this stage, the final evaluation of the challenge was carried out. It should be noted that the evaluation has developed progressively through the milestones defined in the challenge process. An evaluation system was developed in which the results of the formal and informal evaluations were evaluated. In the aforementioned system, the developed learning was collected and analysed, and the decision-making process was followed as the challenge progressed. Four follow-up sessions were carried out based on the milestones. In these four sessions, the different groups made presentations of the progress of the challenge based on established planning (van den Beemt et al., 2023) .The final evaluation was carried out taking into account the aspects included in Table 4.

Table 4. Final evaluation structure

Assessment Category	Assessment Subcategory	Description
Technical assessment (60%)	Technical memory (45%)	Definition and description of the technical solutions developed to address the challenge
	Defending (45%)	Individual questionnaire for each of the technical aspects of challenges
	Sales results (10%)	Sales capacity of the solutions proposed in the challenge
Transversal assessment (40%)	Cross memory (50%)	Level of writing and structuring of the memory
	Final presentation (50%)	Evaluation of the final presentation of the challenge

4. Conclusions

These educational and teaching activities demonstrated that CBL as a pedagogical method can be applied to logistics and operations management education and can effectively promote independence in learning, positivity and cooperation among students. This gives MUDOLP students the opportunity to explore the challenge with an experiential learning model, focused

on solving a real-world problem and proposing creative solutions. It has also offered students a dynamic of participation and confidence that has increased as the challenge progresses. All of this generates a positive expectation on the part of students and instructors towards the applied model (Lara-Prieto et al., 2023). In addition, it has been found that CBL provides MUDOLP students with a foundation for developing project management, communication and coordination skills (Woschank et al., 2022), as well as skills related to industrial process variability analysis, continuous improvement modeling, sustainable manufacturing, people-centered manufacturing and Lean Six Sigma methods, as a basis for developing the differential problem solving task described in Table 1. These are all important characteristics that company operations managers must possess to achieve operational excellence. In summary, the CBL is a learning strategy that can help MUDOLP students to have the necessary 21st century skills to solve the problems they face in the complex manufacturing environment in order to achieve excellence in industrial processes.

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