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Integrating Companies and Higher Education in the Teaching-Learning Process of Lean Thinking Using Challenge-Based Learning

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Abstract

Manufacturing companies constantly search for graduates who know more about Lean Manufacturing to reduce waste and improve productivity. This paper presents a model that integrates teaching Lean Thinking in higher education within an organization's facility using Challenge-Based Learning (CBL). The main objective of the Challenge is to apply Lean Thinking and its tools to improve a Key Performance Indicator (KPI). The model has two main sections: academic and organizational perspectives. While the academic focus is on the curriculum requirements, the challenge, and the evaluation, the organizational perspective covers all the operations management among the university, students, and company. One of the requirements is that the company presents real-world problems for students. The company benefits from CBL by selecting outstanding engineers for future hiring, updating problem-solving tools, and generating innovative ideas to implement Lean Thinking. We conducted the MUSIC® model of motivation to evaluate how motivated a student was during the model and its usefulness. The results suggest that using CBL maintains students' interest in Lean concepts. The model has also shown an acceptable percentage of Lean projects reaching the goal established by the company (63.24%). The proposed model can be replicated easily; however, the student's motivation results might not be generalized.

Keywords: Challenge-based learning, Lean Thinking, Educational Innovation, Higher Education, Industrial Engineering, MUSIC Model of Motivation.

Introduction

The development of a country is mainly based on the type of industry it has. Mexico has 5,153 assembly companies that provide 2,689,209 direct jobs nationwide [1]. Moreover, Mexico has many Small and Medium-sized Enterprises (SMEs) trying to compete against huge companies. The necessity of having Industrial and Systems Engineers (ISE) with both technical and soft skills to improve an organization's performance is crucial. Mexico not only has to make changes to avoid being left behind due to the low-cost workforce that other countries have, but it also has to offer diversity in products and services to increase its competitive advantage [2].

Every day, companies increase their need to hire graduates with a greater capacity for complex problem-solving. For such reason, universities have been using active learning techniques such as Problem-Based Learning (PrBL), Project-Based Learning (PBL), and Challenge-Based Learning (CBL), which have helped students to play an active role in their learning process thanks to the involvement in real-world problems [3].

One of the main objectives of ISE graduates is to have a breadth of perspectives in their field and a deep knowledge of Industrial Engineering concepts. However, when ISE alumni graduate from a traditional learning model, they find it hard to execute the concepts to real-world problems. As a result, there is a lack of credibility in the current education system [4]. Faced with this situation, a change is expected in the teaching-learning process. Therefore, students should develop disciplinary and transversal competencies. These give them several skills: communication, decision-making, teamwork, time management, leadership, and commitment. However, it is vital to have the support of an organization or company that fulfills the role of Training Partner (TP).

One of the big challenges for universities is to put different teaching-learning models into practice to allow students to transfer their learning from "mental knowledge" to a "practical application" of knowledge [5]. The role of both student and professor will be more active; professors will become mentors and evaluators along with staff from the organization that serves as TP. In summary, the main contributions of the study are:

- a model of how to successfully teach Lean Thinking through CBL for Industrial and Systems Engineering students;
- a teaching-learning model of Lean Thinking in collaboration with organizations;
- best practices applying CBL for undergraduates in Industrial and Systems Engineering.

Background

Three didactic techniques are considered active learning: Problem-Based Learning (PrBL), Project Based Learning (PBL), and Challenge Based Learning (CBL). It is essential to differentiate them to apply each technique effectively [6]. However, these didactic techniques are used to develop an environment for solving complex real-world problems [7]. For instance, PrBL focuses more on the learning process than the results of the solution [8–10]. Also, PrBL uses possible or fictitious situations so the student can present a viable solution [11]. Thus, professors need to narrow the problem or project so that it remains controllable [8].

In contrast, PBL focuses on the students producing a product or implementing a proposed solution. Meanwhile, CBL focuses more on the learning process than the results. To better understand the three didactic techniques, there is a study that analyzed them based on four categories, i) the teaching-learning process, ii) the focus, iii) the product or result from those students present at the end, and iv) the professor's role. In addition, the authors mentioned that the key to a successful CBL is the role of the TP that presents real-world problems to solve. Thereby students are satisfied with both solving the problem and proposing solutions [12].

Different countries and universities have used CBL as a teaching-learning process in higher education. A recent CBL study mentioned that most of the research done on CBL is from Spain and the United States, followed by Mexico and Sweden [3]. The authors divided its analysis into four topics; the first is how CBL is used as a background of educational intervention; the second discusses the results of such intervention; the third analyzes CBL with other theories or teaching techniques; finally, the fourth focuses on different theories. The latter two are important because they may conduct how to implement CBL in higher education from a complex systems perspective. Some of the benefits that have been highlighted by implementing CBL to students are networking with industry, improvement of their technical skills, working in a real-world environment with multidisciplinary teams, enhancement of their problem-solving process, and deeper understanding of concepts [13]. Nowadays, industry demands engineers with more than just technical knowledge, and they should understand the complexity of contemporary times [10, 14, 15].

Much of the literature on CBL applied in ISE pays particular attention to the experimental learning space, which might vary depending on the challenge, from production lines to service facilities [16]. For such reason, a semester is composed of 16 weeks, in which half of the students' time is for taking several courses, while the other half is for them to work in the company to solve the challenge. In the spring of 2016, we implemented an *i-Semester* for the first time. Since then, this initiative has been put into practice at the School of Science and Engineering with the support of several companies as TPs. Two of the main pillars of an *i-Semester* are the necessity of having a TP and the implementation of CBL as the teaching-learning technique.

This research presents a model of an *i-Semester* with the implementation of CBL to ISE students in a private university in Mexico. Due to the implementation of Lean Thinking and its tools, the semester for ISE is called *"Kaizen i-Semester"*. The model was successfully implemented for nine semesters to 812 undergraduate engineering students. To measure how motivated a student was regarding the *i-Semester*, the MUSIC® Inventory model was implemented to evaluate the degrees to which a student perceives eMpowerment, Usefulness, Success, Interest, and Caring [17, 18].

The Model

The main objective of the *Kaizen i-Semester* is "to understand how a process works, evaluate the sources of waste (*muda*), and implement Lean Manufacturing tools to improve a KPI". Lean tools eliminate waste from processes to deliver customer value at minimum cost with the best quality [19]. The *Kaizen i-Semester* lies mainly in coordinating two perspectives: academic and organizational. While the academic perspective focuses on fulfilling the curriculum, the challenge, and how to grade students, the organizational perspective covers efficient communication among the university, students, and TP. Figure 1 shows each perspective's model and the sections. Each part of the model will be described in the following sections.

The challenge is solved by teams formed of 4 students; from now on, the teams will be called *Kaizen-teams*, *Kaizen* is a Japanese word referring to continuous improvement. The

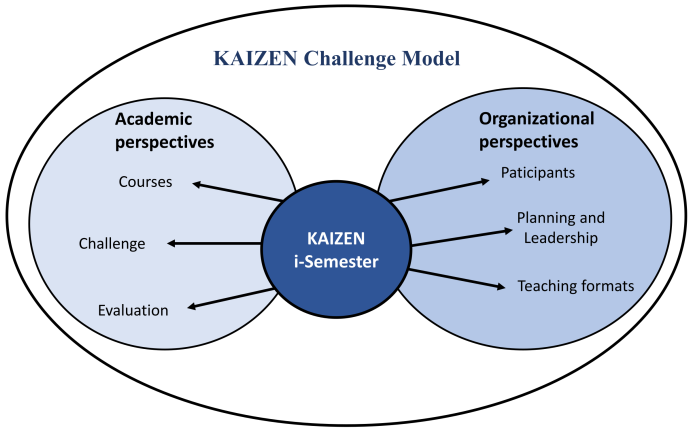

Figure 1: *Kaizen i-Semester Model*

courses in the *Kaizen i-Semester* are Systems Engineering Laboratory, Analysis and Enhancement of Manufacturing Systems, Facilities Design and Material Management, Inventory Management, Production Management, Ethics and Citizenship, and Operational Design and Optimization Laboratory.

The essence of the *Kaizen i-Semester* is the challenge, composed of ten steps divided into four stages as shown in Figure 2. Highlighting students' feedback in each stage is essential to guide them toward better performance. The stages are outlined below.

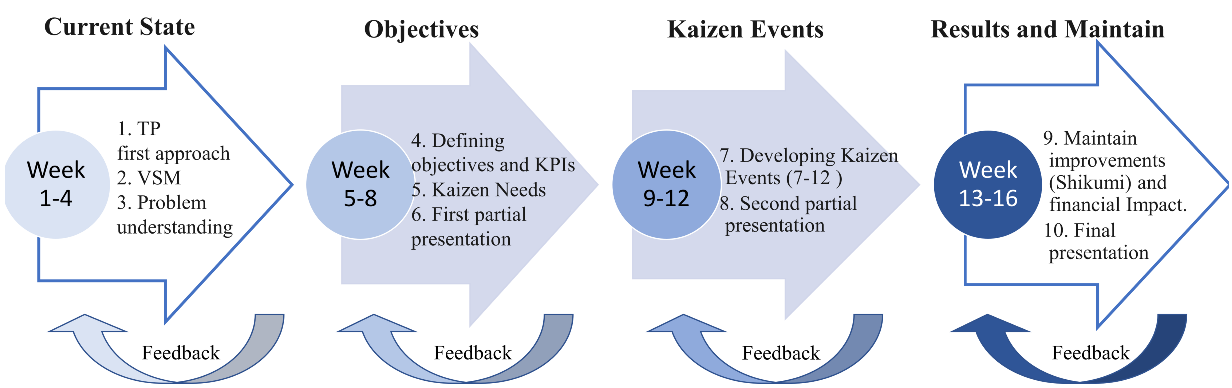

Figure 2: *Kaizen i-Semester Road map*

Current State

1. **Training partner and process first approach:** The students must take an induction course in the company where they learn the safety rules and get access to the areas where they will be working on. In addition, the students visit the process they will focus on during the challenge. The type of projects that students have during the 16 weeks are related to improving productivity in diverse areas, reducing inventory, or decreasing production costs.

2. **Value Stream Map - Current state:** The objective is to understand the current

state of the process and identify the activities that add value and those that do not add value for the customer. Thus, the *Kaizen team* elaborates a Value Stream Map (VSM), which helps to identify *mudas* to reduce or eliminate them by the implementation of Lean principles.

3. **Problem understanding:** The students have to delve deeper into the process and identify the main causes of waste based on an Ishikawa diagram and a Pareto chart. These are two of the most frequently used Lean Six Sigma tools [20]. However, from a systemic perspective, students must present a rich picture illustrating the main elements and their relationship to propose improvements [21]. The rich picture helps to understand the process's richness and complexity. In addition, a rich picture allows stakeholders to engage with other alternatives rather than close the door [22, 23]. The rich picture has been used in the Systemic Lean Intervention process, which helps identify operational issues effectively [24]. Figure 3 exemplifies a rich picture in which the main element is preventive maintenance.

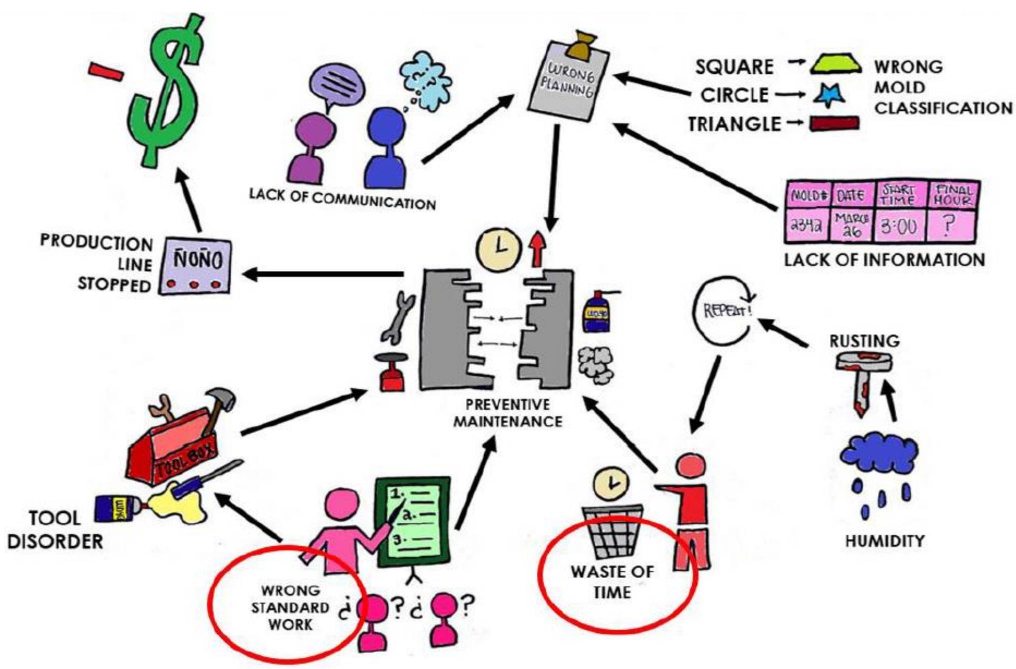

Figure 3: *Kaizen i-Semester* rich picture example for preventive maintenance

Objectives

4. **Defining objectives and KPIs:** Once the problem has been identified with its main causes, the *Kaizen team* establishes the project objective and the target of the KPI. Such a target is approved jointly with the team and the *Kaizen Champion*. The Deming Plan-Do-Check-Act (PDCA) cycle is applied to present the project improvements. For more information regarding the PDCA cycle, refer to [25]. The intent is to synthesize the information, including the KPI, main offenders, primary actions, and follow-up activities.

Figure 4 is divided into four quadrants; the top right quadrant shows the Pareto chart or the Ishikawa diagram (Plan). The Pareto chart identifies the top offenders of the KPI, while the Ishikawa diagram represents the root causes of the problem. The bottom right quadrant represents the action plan to diminish the top offenders. Also, it shows who is responsible and the timeline for each activity (Do). The bottom left quadrant monitors each action (Check). The top left quadrant follows up the KPI according to the established goal. Also, the graph represents a timeline of 16 weeks, where the improvements are shown (Act). Finally, the cycle repeats until the goal has been reached.

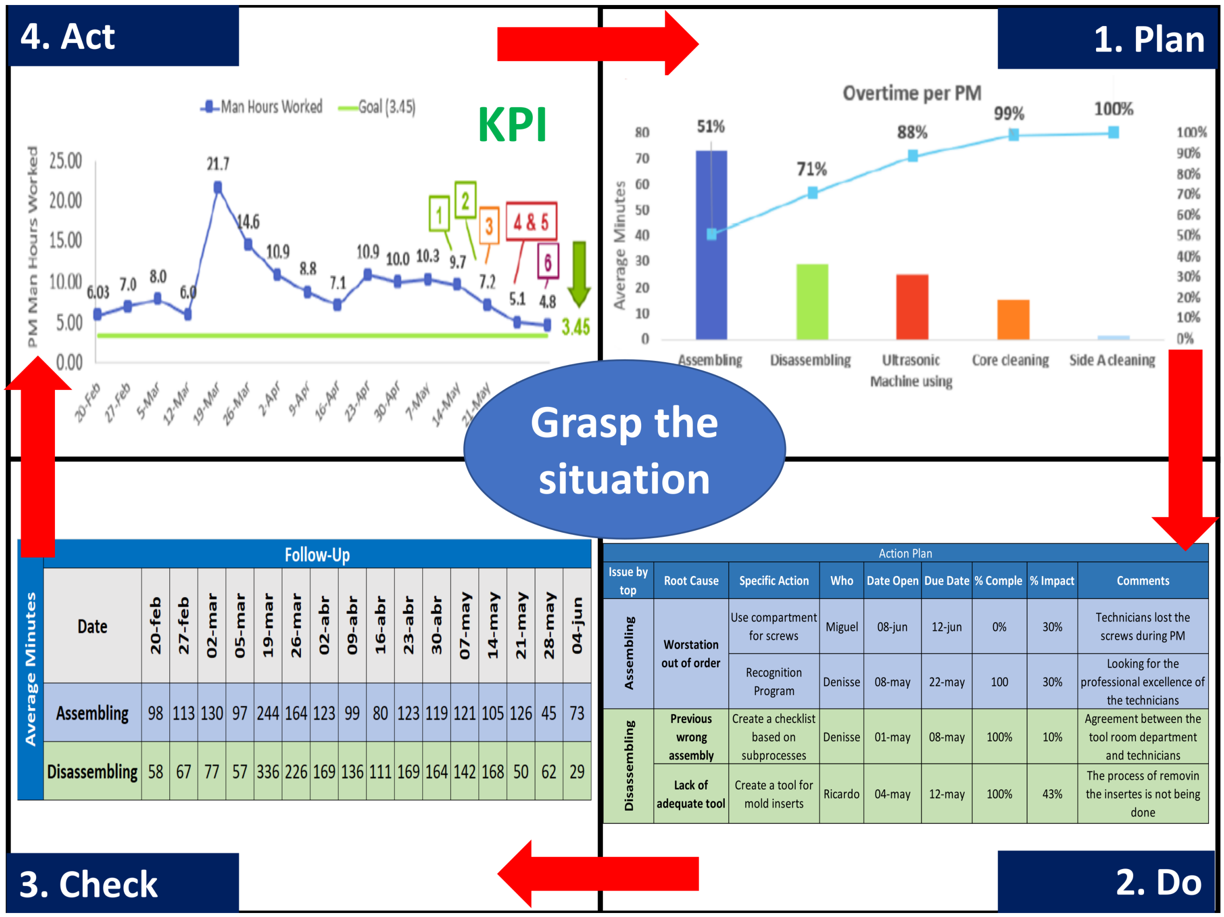

Figure 4: *Kaizen i-Semester* PDCA example

5. ***Kaizen needs*:** To achieve the goal, several *Kaizen needs* are established, mainly Lean Manufacturing tools. At this point, students have the knowledge from their academic modules to propose and implement such Lean tools. In addition, the *Kaizen team* presents the current state, the target to be achieved, and several risks associated with the implementation.

6. **First partial presentation:** The *Kaizen teams* present the progress to a panel composed of professors and company staff. A team member responsible for presenting and answering the questions is randomly selected. Each team has 3 minutes to

synthesize and present relevant information about their project's progress, including the rich picture, VSM, Ishikawa diagram, PDCA, and *Kaizen Needs*. Then, the presenter answers approximately 10 minutes of questions from the panel. After the presentation, feedback is given to each team for continuous improvement.

Kaizen events

7. **Developing *Kaizen events*:** Once the *Kaizen needs* have been approved, the next step is to execute them in the range from 7 to 12 *Kaizen events* to meet the goal. There has to be enough documentation of the before-and-after measures of the executed projects as proof of implementation, as shown in Figures 5a and 5b in which a new layout was made to improve the production line. For more information regarding the implementation of *Kaizen needs*, refer to [26]. In addition, Small Group Activities (SGA) is used for the *Kaizen events*. SGA, also known as continuous improvement or "Quality Circles" in the Japanese industry, is a method for problem-solving in teams by structurally searching for the root causes and eliminating them [27]. A detailed work showing two SGAs and the PDCA cycle is presented in [28] with the main objective of reducing the scrap on a production line.

(a) Before *Kaizen* (b) After *Kaizen*

Figure 5: *Kaizen* event example

8. **Second partial presentation:** Similarly, the presentation dynamic is the same as the first. However, in this presentation, the *Kaizen team* must include the results of the *Kaizen events* along with the impact on the KPI.

Results and Maintain

9. **Maintain improvements and financial impact:** To ensure continuity in the improvements, the *Shikumi* methodology is used, which means setting up the necessary things, such as operation manuals, standards, new methods, or rules, so the improvement is maintained. Likewise, the person responsible for the continuity and period-

icity of execution is assigned. Finally, the financial impact is presented in hard and soft savings. This latter must be authorized by both the *Kaizen Champion* and the financial department. The *Kaizen Champion* is an individual with the expertise to teach and to lead others for the company's Lean initiatives.

10. **Final presentation:** The *kaizen teams* present the results. Initially, they start with a *Gemba* walk through the main areas of their *Kaizen events*. Subsequently, a team member has five minutes to synthesize and present all the work done throughout the semester, including results of the *kaizen events*, improvements on the KPI, *Shikumi*, and financial impact.

Evaluation

Table 1 shows how each course grade is composed. For example, for one course, 50% of the grade is for the theoretical modules, while the other 50% is for the Challenge. the challenge includes six evaluations during the semester. The individual competencies, intermediate presentations, and final presentations are evaluated by a committee composed of professors, TP staff, and *Kaizen champion*. In contrast, the mentor evaluates the final report and the mentoring commitments.

Table 1: How the final grade is composed

Course Modules	**50%**
+	
Challenge	**50%**
1^{st} Intermediate presentation	5%
2^{nd} Intermediate presentation	7.5%
Final presentation	12.5%
Final report	7.5%
Mentoring commitments	5%
Individual competencies	12.5%

Professors oversee evaluating the concepts, teamwork, and competencies. Similarly, the *Kaizen Champion* grades the Lean implementation tools but not the concepts. The students assess the teamwork because they know each team member's work. The mentor is the only one who evaluates all the categories due to the follow-up she/he gives to each team. Most of the disciplinary competencies are evaluated via coursework, except the transversal competencies, which are exclusively graded in Ethics and Citizenship.

Table 2 shows a sample rubric used for the presentations. Several concepts that the rubric evaluates include from time presentation (3 minutes for partial presentations and 5 minutes for final presentation), *Kaizen events*, achievement of the goal to how the students answer the questions made. The total points exceed 100 due to the number of team members. At the end of each concept, we recommend adding a column for comments; these will be helpful during the feedback.

Table 2: Sample Rubric for presentations

Concept	**Points**
On-time presentation (3 min)	20
Presentation format, updated graphs, and complete data.	10
Is there a video that helps to understand the problem or the *Kaizen event* implementation?	10
Presentation, fluency, mastery of the scenario, and correct technical language. Pre-presentation preparation is perceived.	8
There is a relationship between Lean tools, PDCA, KPI, Pareto, Critical To Quality (CTQs)	12
Is the goal reached in the KPI or there is a positive trend?	5
Kaizen events are fully implemented and have an impact on any of the Pareto top offenders	20
Answer questions correctly (at least 5 questions, 5 points each)	25
Total points	**110**

The key aspects of mentoring can be divided into attitude and communication, discipline and responsibility, and results. Attitude and communication include that all team members must actively participate in meetings and workshops, listen to others with empathy, understand their points of view, and avoid preconceived ideas and judgments. Discipline and responsibility cover the development of the activities assigned to each member, considering that these are measurable and realistic. Also, the responsibilities and risks of implementing those activities are assumed individually or as a team. Finally, results focus more on taking the initiative in the search for solutions and adapting to the environment.

Participants

Figure 6 shows the relationship between participants of the *Kaizen i-Semester* for the Industrial and Systems Engineering Department and the TP. The students are undergraduates of ISE in their fifth semester. The only requirement to get into the *Kaizen i-Semeter* is that they have cursed the class of Work Design. The Academic Coordinator ensures that all the activities are performed as scheduled. The head of the Department of ISE assigns the professors teaching the academic modules and the mentor. The role of professors is to teach concepts and guide students throughout the challenge. At the same time, the mentor is responsible for giving feedback after each presentation for continuous improvement. However, a mentor can also be a professor or only a mentor. The Program Director is responsible for everything related to students' life inside the university. The TP assigns the *Kaizen Champion*, the process owner, and the continuous improvement coaches.

The *Kaizen Champion* guides the *Kaizen Team* in the execution of Lean Manufacturing tools. Each *Kaizen Team* has 4 or 5 students and a process owner who assists the team during the Challenge. The continuous improvement coach instructs students during the implementation, while the mentor advises, guides, and evaluates the progress of each team. Students have weekly meetings with their mentors to evaluate their progress. In addition, they must constantly communicate with the workers for feedback on the improvement projects in *Gemba*. Students necessitate the workers' support for the implementation and continuity of the improvements.

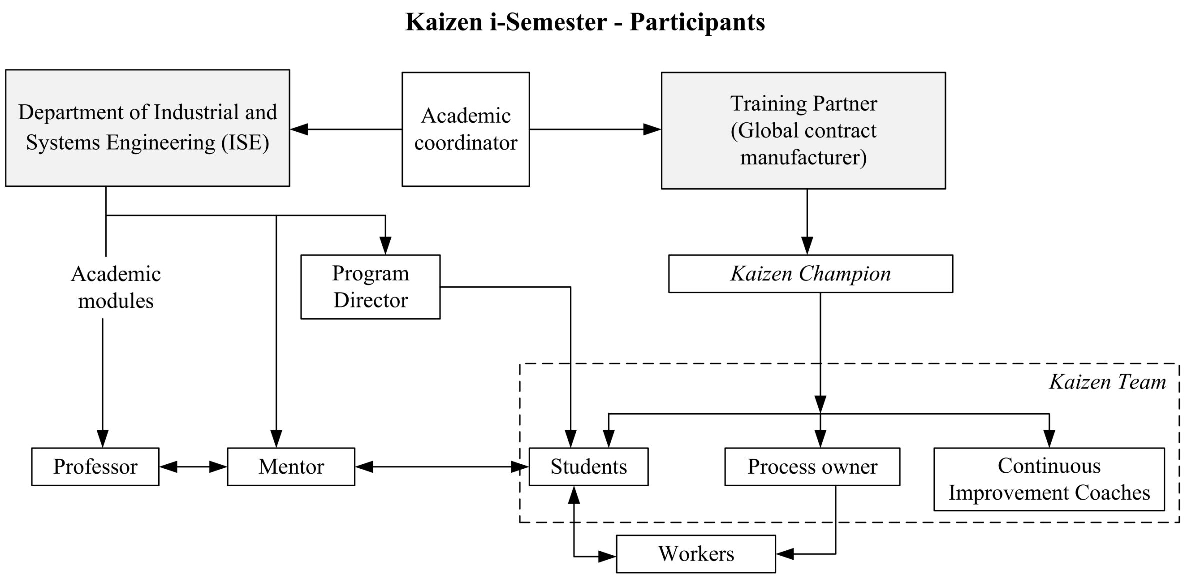

Figure 6: *Kaizen i-Semester Participants*

Planning and Leadership

The logistics for a *Kaizen i-Semester* is divided into three stages. Stage one covers the management before the semester starts; stage two involves all the activities with the participants during the timeline; stage three is the semester closure.

Several activities considered part of stage one must be done before the semester starts. For example, a contract must be signed between the university and the TP each term to establish the legal framework for the challenge. In addition, students must sign a Non-Disclosure Agreement (NDA) to protect the TP's sensitive data and a disclaimer establishing that the student's health insurance plan will cover the case of an accident or injury expense. While the students are enrolled, they must have a major medical expense insurance plan.

The Academic coordinator agrees with the TP on the schedule for the semester, such as the kickoff, intermediate presentations, final presentation, days off, and the dates on which the milestones should be achieved by the *Kaizen teams*. The students and their parents attend the kickoff in which they get to know the TP, where the students will be working, what they will be learning through the challenge, and which competencies they might accomplish. Finally, the students meet their *Kaizen team*, the continuous improvement coaches, and visit the process.

Stage two covers all the activities during the semester, such as the weekly meetings with professors, the Program Director, the Academic Coordinator, *Kaizen Champion*, and the mentor. Throughout the reunion, they discuss how the *Kaizen teams* perform for both the challenge and teamwork. The printed rubrics to assess the performance of the *Kaizen teams* during the intermediate and final presentations are exposed to verify that all the evaluators know how to fill them. For instance, to standardize evaluation criteria among evaluators, it is discussed which work is considered excellent and which is not or what are the minimum requirements. Finally, during these meetings, the schedule is reviewed to verify if there are adjustments.

Stage three covers mainly the final presentation, where the students' parents are invited along with other professors or personnel of the company to see the work done by each *Kaizen team*. The main parts of the final presentation cover i) the final *Gemba* walk, ii) the final presentation of each *Kaizen team*, and iii) the final evaluation.

After the final presentation, the *Kaizen champion* provides individual feedback to each student to know how other members see them. The TP ranks the *Kaizen teams* members in terms of their performance. If there are doubts regarding the grade, the Academic Coordinator offers individual feedback to clarify all the concerns. There is an open invitation to those students interested in seeing the results of the *Kaizen events* to visit the facilities afterward.

Teaching formats

To implement the *Kaizen i-Semester*, professors and TP have three teaching formats in which the teaching-learning process occurs.

- Classes: The learning modules for each course were designed to support the *Kaizen i-Semester* to provide theoretical and practical knowledge to solve the Challenge [7]. To teach the theoretical modules, professors use a traditional classroom with technological resources that consist of a projector, whiteboard, desks, and chairs with wheels that facilitate teamwork.
- In-site classroom: The university has an in-site classroom at the TP facilities for classes and to see real-time processes. Also, it is used to show students how Lean Manufacturing tools are implemented and how they work on the production floor.
- *Gemba*: The students visit and see the current process to understand how it works, ask questions, and learn. The main objective is to comprehend the process to be analyzed outside and propose improvements to reduce waste *(muda)*. Commonly, if there is a *Gemba* walk, the students are accompanied by their Continuous Improvement Coaches or the *Kaizen Champion*.

Results

The study set out a model to implement CBL for Industrial and Systems Engineering undergraduates. Through the *Kaizen i-Semester*, students collaborate with academia and industry to solve real-world problems. Students develop skills and competencies (disciplinary and transversal) to help them tackle industry and organizational problems with a Lean approach as future engineers. Implementing CBL is inherently challenging for professors since they must ensure a clear relationship between the learning objectives and the challenge. In addition, professors encourage students in their learning commitment. Therefore, the evaluation relies not only on the theoretical concepts but also on the proposals, solutions, and how the concepts are applied to a real-world problem. The professor's role changes more towards being a mentor. Thus, there is more demand for faculty time to guide students in the decision-making process, prepare dynamic courses, and continue training in CBL [29]. Table 3 reports the number of students that have taken the *Kaizen i-Semester* since Fall 2017, the number of teams per semester, and the number of teams that reached the goal. Of the 68 teams, 63.24% reached the goal by implementing Lean Manufacturing tools. 80.60% of the teams that did not reach the goal had a positive trend, and the rest improved on other KPIs different from the selected ones.

Table 3: Number of students per semester, teams, and teams that reached the goal

Period	**Students**	**Teams**	**Teams that reached the goal**	**Period**	**Students**	**Teams**	**Teams that reached the goal**
				Fall 2017	38	7	5
Spring 2018	41	8	8	Fall 2018	42	8	7
Spring 2019	52	10	8	Fall 2019	47	6	6
Spring 2020	39	10	1	Fall 2020	19	5	2
Spring 2021	24	6	1	Fall 2021	25	6	3

One of the more significant findings from this study is that, on average, four students per semester are offered positions with the TP. This represents between 8% to 20% of students per semester. The students do not necessarily begin working in the same area. If the student is a junior, the student starts as an intern. Once the student graduate, he/she is invited to have a formal contract if and only if the student shows a satisfactory performance during the internship. The type of job offered to students ranges from Business Excellence leader, Quality Engineer to Program Administrator. It should be noted that the Industrial and Systems Engineering department undoubtedly has relevant benefits in implementing CBL courses within the facilities of a TP because they allow students to solve real-world problems in the industry and get close to how their professional life might become. Likewise, the TP has four benefits to highlight.

1. To empower the in-company *Kaizen teams* with the help of students.
2. To receive innovative ideas for problem-solving from students.
3. To select outstanding students for future hiring as interns or collaborators of the company.
4. To be part of a group of professors that keep updated on Lean tools, problem-solving, and a continuous learning process.

The MUSIC® model of motivation was conducted to evaluate how motivated a student was regarding the model and its usefulness. The MUSIC® measures how a student perceives eMpowerment, Usefulness, Success, Interest, and Caring related to a course, activity, workshop, project, lectures, or homework [17, 18]. In our case, how a student perceives the *Kaizen i-Semester* in the dimensions mentioned before. The user guide on implementing the MUSIC® Inventory Model can be found in [30].

A first sample size was calculated using a statistical power of 90% and an error of 10%; the minimum sample size determined was 57. Thus, the final sample size of 72 students fulfilled the minimum criteria. The sample comprised 35 women (51.39%) and 37 men (48.61%) of the nine semesters. The MUSIC® Model considers five components:

1. eMpowerment refers to the control of the student's environment in the course.
2. Usefulness concerns how the coursework is useful for the student's future.
3. Success relates to whether the student can succeed at the i-Semester.
4. Interest focuses on whether the instructional methods are interesting.
5. Caring pertains to whether the instructor cares about students' success in the course work and cares about students' well-being.

Students who answered the survey rated each component of the MUSIC® model on a 6-point Likert-type scale ranging from "strongly disagree" to "strongly agree". The model has been proven to have good internal consistency (alpha = $0.87 - 0.92$) [31, 32]. The Cronbach's alpha for each component is 0.70 for eMpowerment, 0.77 for Usefulness, 0.62 for Success, 0.78 for Interest, and 0.75 for Caring, representing an acceptable internal consistency.

Figure 7 shows the mean for each component. To validate the model presented in this paper, the **Usefulness** and **Interest** components of the MUSIC® Inventory Model are the most important, without underestimating the rest of the components. The **Usefulness** reflects how important has been the knowledge students accumulated for future use, specifically in their professional lives. The standard deviation for **Usefulness** was 0.82, indicating sensitivity in how students perceived the benefits of the coursework. A possible reason might be the students' affinity to Lean tools; some might not like working in manufacturing and are looking for a more administrative job. The **Interest** represents that the selected courses for the semester were attractive enough to help them solve the challenge. The standard deviation was 1.03, which is considerable, indicating sensitivity to a difference of opinions.

The next element of the model is **eMpowerment**, with a mean of 4.39. At first glance, the students felt they could not control the environment. However, as time passes, the students feel empowered by the environment and have real work experiences. One of the aspects of such a result is that the environment depends on the TP and the challenge itself. However, learning through the Challenge-based learning methodology, students learn more by applying Lean tools to processes. Finally, for the **Success** element, the standard deviation was 1.00, while for **Caring** was 0.97. The **Success** represents that students were able to succeed at the challenge. However, students perceived that the challenge was tough

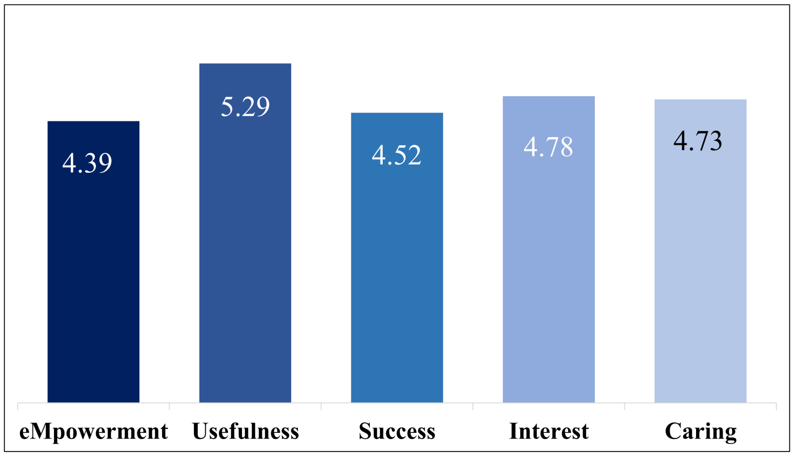

Figure 7: Students' perceptions on MUSIC® components in the *Kaizen i-Semester*

enough but doable. **Success** relates to the **Caring** component regarding how professors bother about the students' Success. These results will likely be associated with the multiple feedback the *kaizen teams* or each student received during the challenge. These results show a good motivation for students to learn Lean Thinking through Challenge-based learning along with a TP.

Conclusions

This study contributes several ways to our understanding of CBL and provides a basis for teaching Lean Thinking in Higher Education. One of the present research aims was to set a model to implement Lean Thinking through CBL. We explained each part of the model in detail, and each section is equally important to a successful implementation. It is worth noting the importance of the TP to the model and the role of the academic coordinator. The latter is the link between the TP and the professors. It is necessary but not essential that the TP has personnel trained in Lean Thinking; if they have them, they can holistically support students in their Challenges.

Although this study focuses on a successful model of teaching Lean Thinking, the findings may have a bearing on the relationship between universities and companies to benefit from working together to enhance education. The present results are significant in at least two major respects. The first is encouraging companies to be TP for different challenges than teaching Lean Thinking due to the four advantages highlighted by the current TPs. The second is the positive results of the MUSIC® Model of Motivation as proof of a successful implementation of CBL to teach Lean Thinking. A greater focus on the first component of the MUSIC® model (eMpowerment) could produce interesting findings that account more for the experimental learning space for ISE students. Since this work used TP's facilities, it would be worthwhile to expand the model to other experiential learning spaces for teaching Lean Thinking (e.g., lean labs, traditional classrooms, simulations, games, or virtual labs).

Finally, we can draw the following conclusions from the present study regarding the best practices for applying CBL to ISE students:

- students have experiential learning through data collection and analysis of current processes through interaction with the TP,
- students implement and validate the improvements in the TP's facilities.
- implement 3-minute presentations to present and synthesize relevant information about their project's progress, developing communication skills.
- students have to work with the TP's personnel to implement their improvements, enhancing teamwork and leadership,
- frequent *Gemba* walks to know and improve the process,
- constant feedback from Lean experts to students.

Ensuring appropriate logistics during all the stages of the *Kaizen i-semester* should be a priority to minimize participant complaints. Also, it is essential to guarantee an appropriate learning platform, effective communication channels, and set dates in advance for all the activities.

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