

Stakeholders' perspective using challenge-based learning and industry partnerships to develop competencies: case study in industrial engineering

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Abstract— Universities have been working in the last decades on the development of competencies of their students, for this reason educational innovations are under strong demand by faculty to achieve this goal. Challenge-based learning integrates elements of problem-based learning, project-based learning and a focus on addressing real industry problems in collaboration models between different stakeholders. This research shares the case study of the educational model of a private higher education institution with national presence in Mexico, which among other elements uses challenge-based learning and a strong linkage with industry with a greater role as a formative partner for students in engineering programs. The study shares the learnings related with the linkage process, from the perspectives of the formative partner and the students, the results of challenges applied in the industrial engineering program in its second and third year of specialization. Aligning the challenge to academic interests as well as the interests of industry with its current problems is a challenge to overcome, which is solved when both entities are aligned in the search for the development of general education and disciplinary competencies in students, which in the end will benefit future professionals with the skills, values and knowledge to go beyond facing the world to create the world we all want to transform their business and help each other as a community.

Keywords-- Industrial Engineering, Challenge Based learning, Industry Partnership, Higher Education, Innovational Education.

I. INTRODUCTION

In recent decades, the demand for transversal and disciplinary competencies of the profile of any profession is present both in companies in the search for their work team, as well as in formal and informal studies and publications [1, 2, 3, 4]. For several years, competency-based education has been the focus of attention of higher education institutions, which is based on curriculum design, teacher training, strong links with the environment, and evaluation systems that measure the progress of students in each competency until they graduate from university.

As part of the development of a competency-based educational model, a university in Mexico with national presence, proposes a challenge-based learning model with four main elements: challenge-based learning, personalization and

flexibility, inspiring professors and memorable experiences. Beginning in their second year, students take their curriculum with a strong link to the industry or organizations that present problematic situations with needs related to the knowledge and competencies they are developing in their semester and subject.

The study presents the experience of four challenges for the industrial engineering program, describing the challenge for different courses, with a reflection process linked to the objectives for which it was designed from the perspective of the stakeholders: students, professors and educational partner companies.

The educational model that is designed, transforms the curriculum focused on student learning to develop in different levels of achievement, according to their progress in the program, the competencies focused on 3 areas: competencies focused on the engineering area, transversal or general education competencies and disciplinary competencies. Challenge-based learning responds to the need to develop these competencies using real situations that arise in an organization or company during the course of a subject, which is analysed and solved through the application of the content of the modules that are seen in periods of 5 or 10 weeks.

The new competency-based educational model of a Mexican university uses challenge-based learning, linked to training partners, working collaboratively with professors to describe the situation, establish objectives and needs and a work plan for interaction with student teams. Educational partners are companies or organizations with which a university establishes a long-term partnership for the realization of agreed challenges [5].

Challenge-based learning has recently emerged with the need to link the reality faced by companies with learning at the university, through close relationships with companies and organizations as partners in the teaching and learning process of students [6,7,8,9]. The impact of challenge-based learning on students is not only in the development of their competencies, but also in the engagement it generates with the knowledge, and with their discipline, in addition to forming a future vision of what they may be facing once they graduate in the real life of an industrial engineer [10,11].

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program’s competencies for the new environmental challenges based on the Tec21 Model. These five defined competencies are: Innovate organizational processes as an outstanding competence, solutions with a systemic vision, manage multidisciplinary projects, statistics-based business intelligence as seal enablers competencies, and enhance the competitiveness in organizations, implementing quality as the ADN competence for an industrial and system engineer [12]. The representation of these competencies is on figure 1.

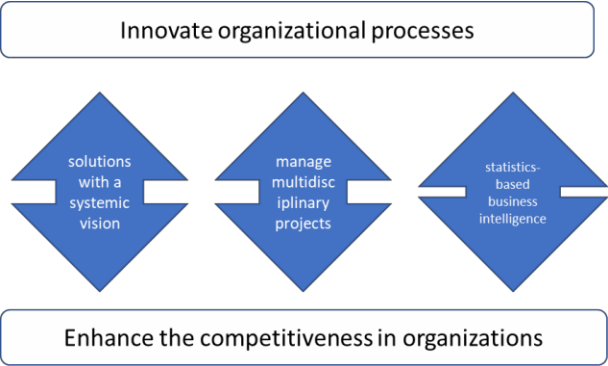


Fig. 1 Industrial Engineering Competencies

The implementation of challenge-based learning is done in several stages:

Course Design stage, where the challenge is designed along with the learning modules that the student should take to achieve, solve the challenge and develop the competencies defined for that training unit or course. In this stage the learning objectives (definition of the competencies to be developed), the characteristics of the challenge, the profile of the educational partner, as well as the analytical contents of the modules are established.

The Design stage of the challenge applied to the Educational partner, is connected with the course to develop the competencies, and the use of the acquired knowledge of the student, through teamwork. This design consists of a description of the challenge, the areas that impact the problem situation, the content’s order for the students’ instruction, as well as stakeholders and interaction agreements with the students (visits to the company, communication, frequency of meetings, data to be provided, etc.).

During the Implementation stage of the course, the challenge is performed, with phases such as diagnosis, solution proposals and detailing of proposals for implementation. The use of technology, data analytics, modelling, quality or innovation tools, as well as project management can be used by the students. During this stage, deliverables are defined as intermediate goals with constant feedback from the educational partner.

Finally, in the Evaluation stage, feedback processes are conducted with students, evaluation of competencies, feedback from the educational partner and a process of reflection by the

professors who teach the course. During this stage the evaluation of the challenge has a collaborative phase, and the competencies evaluation has an individual phase. It is important to clarify that in this challenge-based learning model, a team of teachers are the ones who design and carry it out in collaboration with the educational partner.

II. APPROACH

The methodology is mixed [13], considering the perspectives of the previously mentioned stakeholders, students, professors and company or educational partner organization, using surveys and interviews that allow comparing the perceptions of the fulfillment of the course objectives as well as the development of competencies and the role according to the established educational model. The study consists of a description of the challenge with the students, a description of the problematic situation of the educational partner, the application of surveys to students and educational partners, and the professor's reflection on the challenge developed with the students.

The cases analysed were conducted at 3 different campuses of the same university located in the center and north of the country: Estado de Mexico, San Luis Potosí, and Nuevo León, made up of students whose courses are in the 4th semester (2nd year of their study plan), 5th and 6th semester (3rd year of their study plan) (see Table I). In addition, there were two companies in the manufacturing area and one company in the service area. In the latter company, two challenges of two different courses were developed in a continuous manner, but at the same time linked by the type of content offered in each course.

TABLE I
COURSES AND EDUCATIONAL PARTNERS

Course	Academic year & Location	# of Students	Company type
Improvement of an Adaptive Value Chain Challenge 1	3 rd year / Nuevo Leon	36 (7 teams)	Manufacturing company (20 employees)- Challenge 1
Improvement of an Organizational Process with Statistical Methods Challenge 2	2 nd / Estado de México	32 (5 teams)	Manufacturing company (+ 200 employees)- Challenge 2
Organizational Competitiveness Evaluation Challenge 3	3 rd year / San Luis Potosi	10 (2 teams)	Service company (hotel, 50 employees)- Challenge 3
Analysis of the Viability of Projects from a Systemic Perspective Challenge 4	3 rd year / San Luis Potosi	10 (2 teams)	Service company (hotel, 50 employees)- Challenge 4

A description of the challenges in general from the perspective of the course, and the specific challenges that the training partner defined together with the team of teachers, are presented below:

Challenge 1: In the course of an Adaptive Value Chain, the challenge was to develop an innovative, creative, feasible and viable proposal that contributes to improving the efficiency and sustainability of the supply chain of a real organization, using technology, information and mathematical modelling tools.

The educational partner offered two types of challenges: one related to the management of its raw material inventory for several production lines, and the other challenge, transforming the distribution of its products from distributors to direct deliveries to the end user.

Challenge 2: In the course of Improvement of an Organizational Process, the challenge is to analyse and improve a real process using statistical tools.

The company offered the challenge as the ways to Improve the Overall Equipment Effectiveness (OEE) indicator by identifying root causes of unscheduled line stoppages. The areas where the challenge was developed were: the production area (casting molds for automotive industry parts) and the foundry area.

Challenge 3 & 4: With the courses of Organizational Competitiveness Evaluation and Analysis of the Viability of Projects from a Systemic Perspective, students develop a participatory diagnosis, knowing the competitive strategy, identifying key processes and factors affecting competitiveness.

The hotel presented the challenge of improving the housekeeping area, which impacts productivity and service, and the generation of preventive maintenance for the maintenance area. In the fourth Challenge, the students conducted the evaluation of the feasibility of proposals for the housekeeping and maintenance area.

A survey is designed to be applied to the Educational partners to provide their perspective and documented feedback. The sections of the instrument were:

- General characteristics of the Educational partners, including whether they have already participated in previous periods and challenges. This information tells us about their satisfaction in continuing to participate in the process. They are also being asked what other type of involvement they have had with the institution, such as offering internships to students.
- The second section asks them to describe the problem situation that integrated the challenge as well as the area where it is developed, if the development of the challenge met their expectations, and the level of difficulty to adapt to the collaborative process with professors and students.

- The third section is related to the linkage, how it was created, the reasons why the linkage is desired, if they wish to continue as a Educational partner, and the recommendations they offer to improve the linkage process and the development of the challenge.

III. RESULTS AND DISCUSSION

The results are presented from the perspective of the three stakeholders: the students, the educational partners and the professors, each one of them fundamental actors to achieve the development of competencies in the students themselves and based on Model Tec21. For Tecnológico de Monterrey, this new educational model responds to the actual needs of the environment. Traditionally, academic programs at the degree consist of a sequence of courses that make up the study plan (curriculum). When a student completes his study plan satisfactorily, the university confirms that the student has a certain level of development to perform successfully as a career professional. In this Model, the central unit of learning is the courses that make up the curriculum. Model TEC21 considers that student's learning during their undergraduate studies is focused on the student's relationship with his teacher and with the educational partner, in which students develop disciplinary (area and program) and transversal skills, through the resolution of challenges related to real problems, and demonstrate their dominance through various learning evidence. In this model, the central unit to learning are challenges [14]. The model's representation can be appreciated on Figure 2.

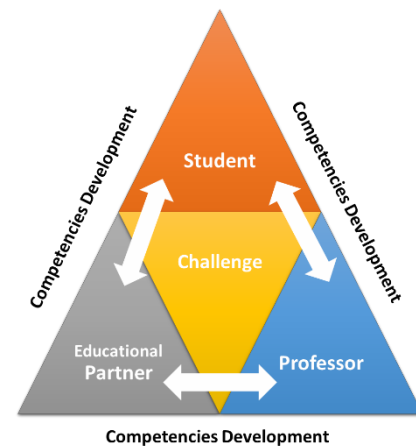


Fig. 2 Educational model [14]

The following first describes the results generated by the students, working collaboratively, for the educational partners according to the established challenges:

Challenge 1. The educational partner defined two challenges to develop linked to the supply chain, one focused on inventory management and the other on new distribution

processes to reach the end customer without intermediaries. The teams were divided in half, and each team developed its diagnosis process by understanding and mapping key processes, as well as the information required in each part of the supply chain. Site visits were conducted with representatives from the teams complying with pandemic health regulations. With constant meetings during the week through digital media such as zoom, use of WhatsApp as well as visits, information was shared to understand the problematic situation, and the areas of opportunity found. Interviews and observations were used as instruments to collect information, as well as data analysis provided by the company itself. The proposed solutions were linked to the distribution of spaces, analysis of competitors, use of technology, dashboard design, to name a few.

The professors participated with the educational partner in the clarification and definition of the challenge, as well as in the understanding of the processes related to the value chain. The organization is considered a small company due to the number of employees, yet the issues discussed are present in both small and large companies. The constant communication and availability with the educational partner were one of the main advantages for the challenge to be carried out in an enriching way both for the students and for the company, which shared its surprises and interest in some of the solutions presented by the teams.

Challenge 2. The challenge was developed mainly in 5 stages which correspond to the DMAIC (Define, Measure, Analyse, Improve and Control) methodology; in the first stage the students made a diagnosis of the production line and established a baseline of the main indicator to measure, in the second stage process mapping was performed, as well as the first data collection of the behaviour of the production line, in the third stage the data were analysed statistically and by means of tools such as FMEA (Failure Mode and Effects Analysis) to look for root causes, in the fourth stage the improvement proposals were elaborated and presented to the educational partner, in the last stage only control and follow-up proposals were mentioned. Among the results, it was possible to identify the root causes of unscheduled production line stoppages, to propose alternative solutions to avoid unscheduled stoppages, and thus, under a control scenario, the OEE could have a positive impact of around 10% at first.

From the faculty's perspective, they find the educational experience very enriching for all three parties, students, educational partner and professors; for the students it is undoubtedly a unique opportunity to develop not only disciplinary but also transversal competencies by having the opportunity to relate concepts and theories to the real world, for the educational partner it is also very enriching because beyond having proposed solutions to a problem they have different points of view, ideas proposed "out of the box" and above all it can help to eliminate the "workshop blindness" to areas that for the company are common things, finally for the professor it

represents an opportunity to update both in the disciplinary field as well as in the field of educational innovation: classes literally become laboratories of experiential learning.

Challenge 3 & 4. The objective of the challenges was to conduct a systemic analysis of the hotel's maintenance in two areas: housekeeping and preventive maintenance. In this way, every detail of the processes was analysed and identified areas of opportunity, in order to establish a specific focus and generate improvement proposals through Lean Manufacturing tools. The educational partner participated constantly in the challenge and the students had the opportunity to attend the hotel in order to interact with the employees. The information they received was through a presentation of the company with information from the managers, interviews with the staff, site visits, observations, a mid-term presentation to get the feedback from Educational Partner to align for the final delivery, and analysis of existing information from the hotel for the final result.

A key point to generate the statement of the current situation of the maintenance department at the Hotel was to conduct the tours with the personnel, both the management, the housekeeping department, and the maintenance department, as well as operational areas. The mapping of the key processes allowed them to identify areas of opportunity and improvement, as well as its strengths. The implementation of different techniques such as 5s and/or the identification of wastes, helped to identify the area where the proposed solutions were focused. Using the 5w 2h methodology, the problems encountered were defined and, consequently, three proposed solutions were generated. These proposals can be used together to eliminate waste, increase efficiency, and improve the timing of its key processes to impact client satisfaction.

From the perspective of the faculty team, it was an extremely enriching and challenging experience. It was to enter a service industry where the students were able to have a real-life experience coming out of the pandemic. Also, it is important to realize that being in a service industry gives to the students the opportunity to participate in a different sector. The openness of the company and their support is vital to the success of the project. Being able to optimize time to gather information and raise awareness of the process is vital. The students had the sensitivity to make realistic, innovative and low-cost proposals for the organization, which was very well received by the organization and the employees, creating a training manual and video. Another significant aspect for the professors is the close relationship that is developed with the Educational partners, from the design stage of the challenge, the definition of the work plan with the moments of interaction of the students with the company and with the staff, as well as during the implementation to be in constant communication according to the monitoring the progress of the student teams during the challenge and with the organization.

From the students' perspective they found that the challenges in general represent common and real problems of

the organizations, they consider the complexity of the problematic situation, they find it linked to the course of their discipline in which they are developing the challenge, as well as interesting for the application of knowledge (See Fig. 3).

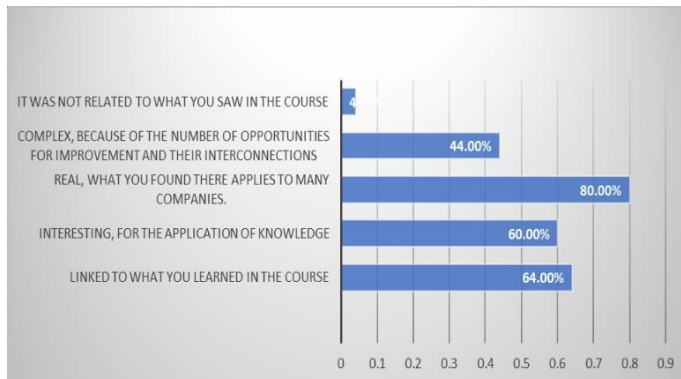


Fig. 3 How would students describe the problems of the Educational Partner

To the question related to the advantages observed by the student of having challenge-based learning linked to a company/organization they responded:

“The proposed solutions can be transformed into real results. Real cases are presented and working with an organization allows us to put into practice what was learned in class more easily.”

“The advantage is that you get to understand as a student the real behaviour of an organization, and it invites you to be prepared to work in a business environment.”

“You are dealing with real problems and real data. It not only prepares you better but also motivates you more.”

“It gives us an insight into work life and the challenges we have to meet in the future.”

In reference to the consultation with educational partners [5,6,7,8,9], the conclusions of their participation with the generation of challenges linked to their current problems, aligned to the particular course of the discipline, the interaction with students and professors for the diagnostic stages and solution proposals, are related to:

- It is interesting to note that the participation of the organizations occurs equally through the invitation of the university to join as a training partner, and also through the initiative of the company itself, seeking to collaborate more actively with the institution.
- The main reasons why the organization is willing to link with the university are the generation of value propositions for the company with different perspectives (continuous improvement) and recruitment of talent.

- The main challenges for the industry with the linkage as an educational partner are the availability of operational staff to attend the students and due to the pandemic, the virtual attendance as well as the size of the group (number of students).
- The three companies confirmed their participation for the following academic periods.

IV. CONCLUSIONS AND FUTURE RESEARCH

This perspective using challenge-based learning and industry partnerships to develop competencies on students is an integral proposal from Model TEC21. The students have the opportunity to interact with real life problems from Educational partner with real needs. Learning is more than theoretical or conceptual, and the main reason is the students' interaction with organizations' members and they have the opportunity to present the results to the top management for the proposal' innovations. The students receive feedback for their personal and professional development.

This learning based on Model Tec21 confirms that students are developing an integral formation with transversal competencies, engineering competencies, and industrial engineering competencies. The benefits for the three main stakeholders are clear, the students win an integral formation, the professors are linked to the community, and they are sensible to the real-world needs, and the organization (Educational Partner) contributes to the development of students and gets closer to the talent it will later have the opportunity to recruit. The combination lets them be in constant learning, and update the concepts. For the Education partner there is a win-win relation, they have a fresh point of view from students but also, they have solutions' proposals for their actual opportunities' areas.

The development of disciplinary competencies as well as transversal competencies are observed with the challenge-based learning model, where the different stakeholders obtain their benefits in addition to those expected by the design of the course and the challenge: (a) for the students, an increased interest in their discipline and how to face real problems, both individually and in teams, with a vision of the future that the environment will offer them once they graduate, (b) for the educational partners, innovative solutions for the current problems faced by their company, and also the opportunity to meet, (c) For professors, the opportunity to inspire students in their disciplines, to keep up to date with the reality in the companies and the opportunity to develop innovation or research together with the companies and students.

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