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A Challenge-based Teaching model for Structural Analysis Courses with Strategic Industry Partners

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Abstract

In this paper we present a challenge based teaching model for Structural Analysis courses within the framework of our education model, namely Tec21 in which some courses are taught with the participation of an industry partner. The content of this course is usually complex and some principles and concepts are difficult for students to associate with a real life application. Contents include Energy Methods, Stiffness and Flexibilities Methods and an Introduction to the Finite Element Method. The main component of the model is the solution of a challenge for which, students work in teams. The challenge presented to students at the beginning of an intense five week period consisted on the design of the structure of an industrial warehouse in a given location. Students have to present a solution applying the concepts seen in the course as well as the local building code requirements. The course is taught by two or three professors and the participation of people from a chosen industry partner, that for the case of this course, it is a professional and chartered structural engineering firm. For the solution of the challenge, the participation of such an industry partner was crucial, as they provided information, advice and recommendations to students in several meetings throughout the five week period. The results included in this paper are from two different implementations of the model in two different campuses of our university system. Two different industry partners participated, one for each location and the challenge was similar in both cases. Some results on student satisfaction and the type of activities that they enjoyed the most are also presented. This work can be used to design new courses related to Structural Analysis that can benefit from the participation of industry partners, as we consider that this type of model can close the gap between those theoretical courses and the design courses that are further ahead in the curricula of Civil Engineering students.

Introduction

The professional workplace has become more and more globalized in the last few decades, and it has become increasingly more competitive in which the use of the latest technologies and digital transformation competences are as important as disciplinary competences. In the last decade, our institution T*ecnologico de Monterrey* has worked in a new educational model, namely Tec21 that is a challenge-based model [1-7].

One of the main characteristics of our educational model is the development of disciplinary and transverse competences in all students, from the implementation of teaching methodologies that are based on the solution of real-life scenarios or challenges, presented to the students at the beginning of a new course. The challenge is a project previously designed by a nation wide team of professors and instructors with the main objective that the solution of such a challenge motivates students to apply the knowledge learned during the class sessions and at the same time, solve a real life scenario related to a discipline of their academic program, e.g. Structural Engineering.

In the design of the challenge, the participation of external entities from Industry is crucial. Within our educational model we call them Strategic Partners, as they play a very important role in the learning process or formation of the new Engineers. In Fig. 1 we can see the virtuous triad that is formed with the collaboration of students-professors and the Environment for which the challenge is designed.

Fig.1 Challenges in our Educational model.

The profile of the Strategic Partner in the courses can include:

- Engineering Firms
- Companies of small, medium or large size
- Public Institutions
- Non Governmental Organizations (NGOs)
- Research Centers
- Communities such as municipalities

The Strategic Partners participate in the definition of the characteristics of the challenge by providing in some cases, real projects that they may have at that time or have already solved in the past. As a result of this partnership, students and professors/instructors can visit some sites or locations that are important for the solution of the challenge, e.g. the site of the construction of a structure.
During the first five weeks of the semester that ran from August 2021 to December 2021, the course named “Evaluation of the behavior of Structural Systems” was implemented using this model in two different campuses located in two different cities in our country. A total of 62 students participated in the two groups, 32 for the Queretaro Campus and 30 for Puebla Campus. This course is related to Structural Analysis topics, including: Energy methods, Stiffness and Flexibilities Methods, Matrix Analysis and an Introduction to the Finite Element Method. The

course is taught in an intense manner, for five weeks students have to work sixteen hours per week, in lecture sessions, solution of the challenge and presentations. For the solution of the challenge, students had to present three different proposals for the structural system to be used in an industrial warehouse in a location in central Mexico, known as El Marques, a region that has many industries related to manufacturing for the aerospace industries. A team of instructors and a professor worked with the students and the Strategic partner in each campus.

There are similar pedagogic models as the one presented in this work, particularly close is the project oriented learning (POL) or the project based learning that have been applied to most disciplines of knowledge, such as Chemical Engineering, Production Engineering, Mechanical Engineering and even Space Engineering [8-20]. In this work we analyze the impact the challenge and the participation of the Strategic Partner had in the learning process of a course of Structural Engineering within the framework of our educational model using a challenge-based approach. In this study, we also analyze two different modalities for the sessions: hybrid sessions and fully online, as the two cities had different conditions during the pandemic.

Objectives

The main objective of this work is to present the results of the participation of the strategic industry partner in the course that required students to present the solution to a real life scenario or challenge, particularly, the proposals for a structural system of an industrial warehouse.

The course had a total of 80 hours in five weeks was taught in a hybrid format in our Queretaro Campus, whereas the Puebla Campus was still in strict lock down and had to be taught in an online format. In the case of the hybrid group, the allowed percentage of students in the classroom was limited to 50%, so a maximum of 16 students were present at any time, and the rest connecting in real time via Zoom. In the online group, all sessions and meetings with the strategic partner were held online using Zoom.

The participation of the Strategic Partner included several meetings with each team of students, the whole group for each location and some feedback sessions in which the Professional Engineers from those Engineering Firms (Strategic Partners) advised students and gave their opinion about the solutions in process. The perception of students is also included in this work and how working with a partner from industry motivated their learning and application of the knowledge/theory learned in the classroom.

Methodology

From mid March 2020 until August 2021, all campuses in our university across Mexico were teaching in an online format exclusively, using all available digital platforms such as Zoom. All course were taught in a synchronous way, in real time, and this model we called it the Digital Flexible Model (DFM).

From August 2021, most classrooms in most of our campuses were equipped with large monitors and cameras that follow the instructor, so that a hybrid model could be used, with some people in the classroom and some connected via zoom in a synchronous way to the session of the day.

Lavalier microphones were provided to the instructors and professors and they had to teach in a way that people present in the room and those at home could interact as a single class. This model was called the Hybrid Present and Remote Synchronous Model (HPRS). The idea was that half the group could be present and the other half at their homes. However, conditions in cities were different and local health authorities were providing the maximum number of people in classrooms, based on social distancing and ventilation of the rooms. In some cases, only a maximum of 30% of occupation was allowed.

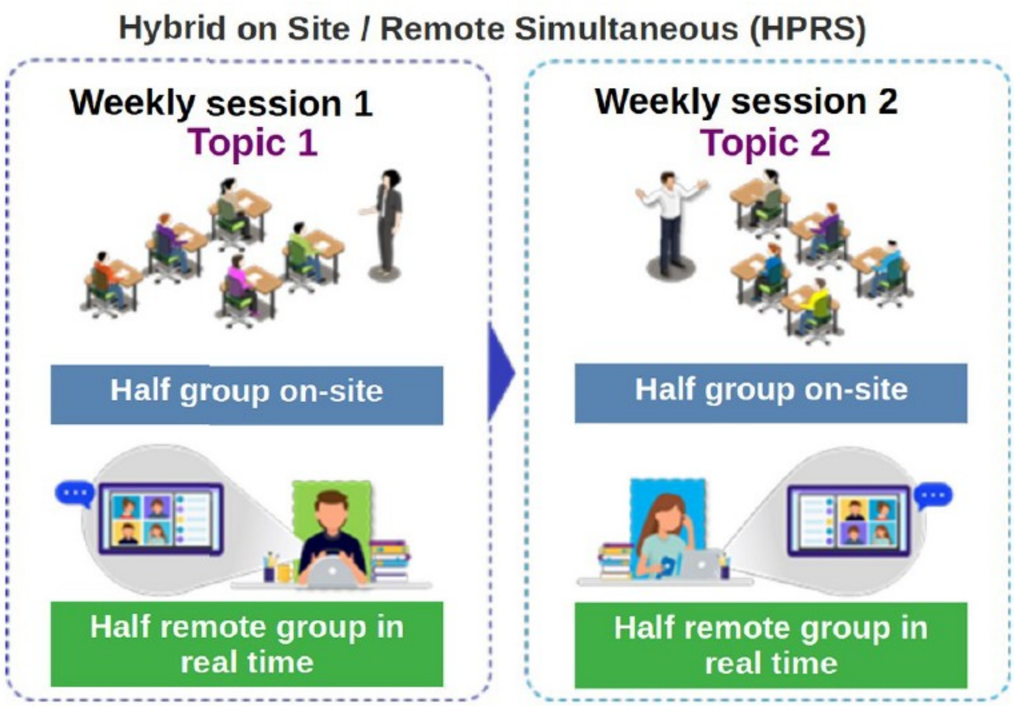

Fig. 2 Hybrid Model in our university : not all students could attend at once because of Covid19 rules from local government.

This paper includes the results of implementing the proposed model in two differentc campuses, with a total of 62 students for the course "Evaluation of the behaviour of Structural Systems" that is part of the fifth semester of the Civil Engineering program. The course consists of five intense weeks with 16 hours of course work per week. It usually includes four days of the week, four hours each day. This was the first time this course is taught, as the new educational model is currently in its third year and the students that took part in this study are the first generation.

A survey was designed with questions regarding the participation of the industry partner, the activities they enjoyed the most and their overall satisfaction, among other aspects of the course. The following sections include the results of the questions and the perception of the students regarding the challenge.

For the development of competences with regard to structural analysis and basic concepts of structural design, the challenge was designed in a way that the students could also propose some solutions for the topology of the structural system for an industrial warehouse, which should include the most appropiate morphology for the site conditions, the needs of the client or user (according to some specifications given by the architectural project), seismic hazard and wind loading for the given site, according to its location (see Fig. 3).

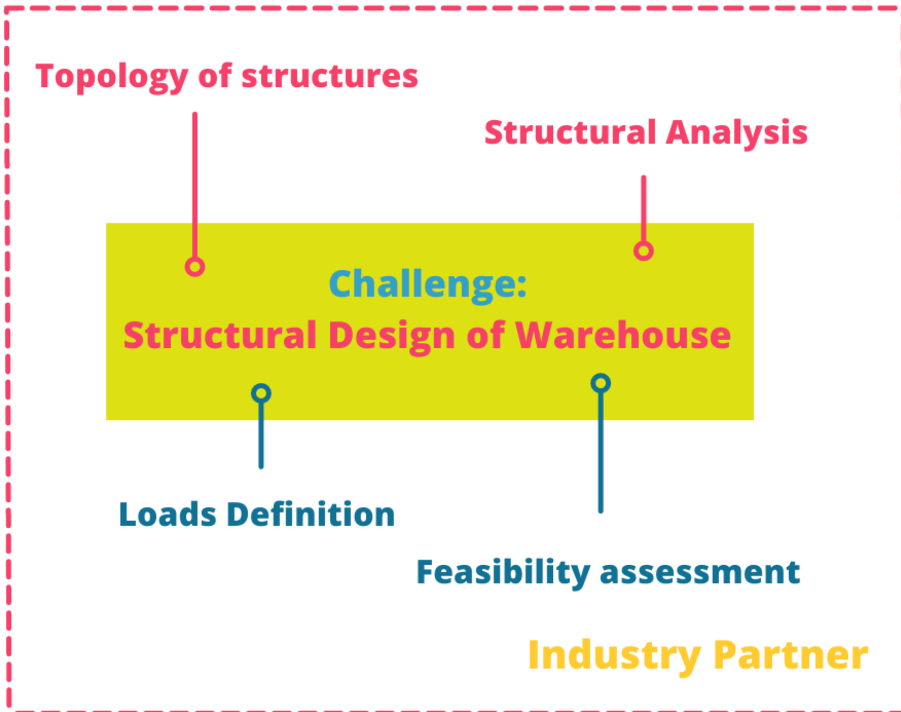

Fig. 3 Challenge: Structural Design of Warehouse

In order to cover all the topics included in the course's syllabus, four different modules were taught by the professors and instructors: a) Structural Topology, b) Classical Methods for Structural Analysis, c) Modern Methods of Structural Analysis and d) Seismic and Wind Loadings in Buildings. Students analyzed different options for the configuration of the proposed structural system and reflected on the benefits and drawbacks of each alternative, applying the theory of Structural Analysis and at the same time, developing some competences for the workplace by applying their knowledge to the solution of a real case scenario.

The teaching of the aforementioned modules included:

(a) Exposition-Lectures of the theory behind Structural Analysis Methods and their history with an emphasis on the main principles and assumptions used in their development.

(b) Problem-solving sessions with examples shown by the professors and instructors and how they relate to the challenge the students have to solve.

(c) Some coding in Python of algorithms of solution for some methods so that students can identify how some tasks are repetitive and can be programmed in a computer.

(d) Use of commercial software for Structural Analysis where students can analyze their proposed systems under different loading conditions.

For the last phase, use of commercial software, the package RAM Elements was used, since the company provided licenses for home use for all instructors and professors. This was critical during pandemic conditions as no access to campuses or laboratories was allowed. The use of commercial software also allowed different loading conditions to be set in their models, especially for the wind loading combinations.

During the first three phases, students were taken step by step by their professors and instructors into the different topics of a structural analysis, as this was their first course on hyperstatic structures. During this stage, students were given some problems oriented or related to the problems they would solve during the solution of the challenge, as a way of training.

In phase 4, as indicated in Fig. 4, the participation of the industry Strategic Partner was crucial because it was in this stage when professional engineers (P.E.) from the Engineering Firms visited the classrooms (on campus and virtually), in order to get to know the proposals of the students and provide them with feedback about the factibility of their solution, the constructability of it and even the costs of such a solution. We believe that this participation is a key element that greatly enriched the course experience for our students and professors/instructors.

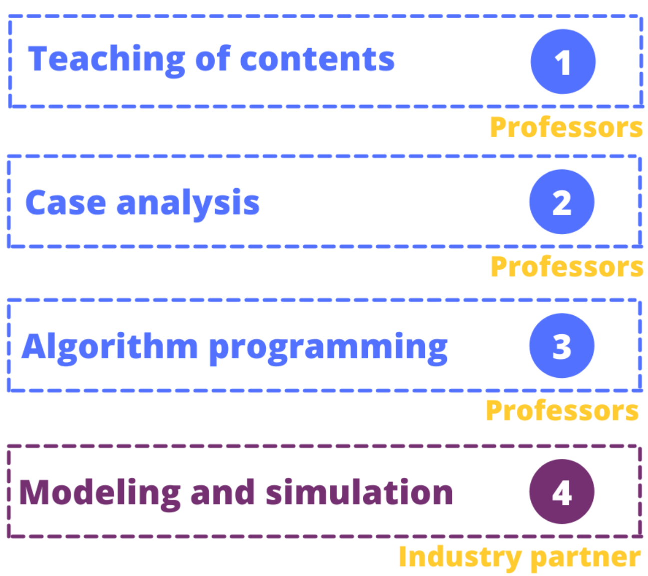

Fig. 4 Workflow of the course

In Fig. 5 we can see a meeting of a strategic partner with the class and a team showing their proposal of structural system for an Industrial Warehouse. In this case this is an example of a virtual meeting in Zoom, so that the whole class can participate and the professional engineers can interact with all of them at the same time, in a week when local conditions did not allow for on campus meetings.

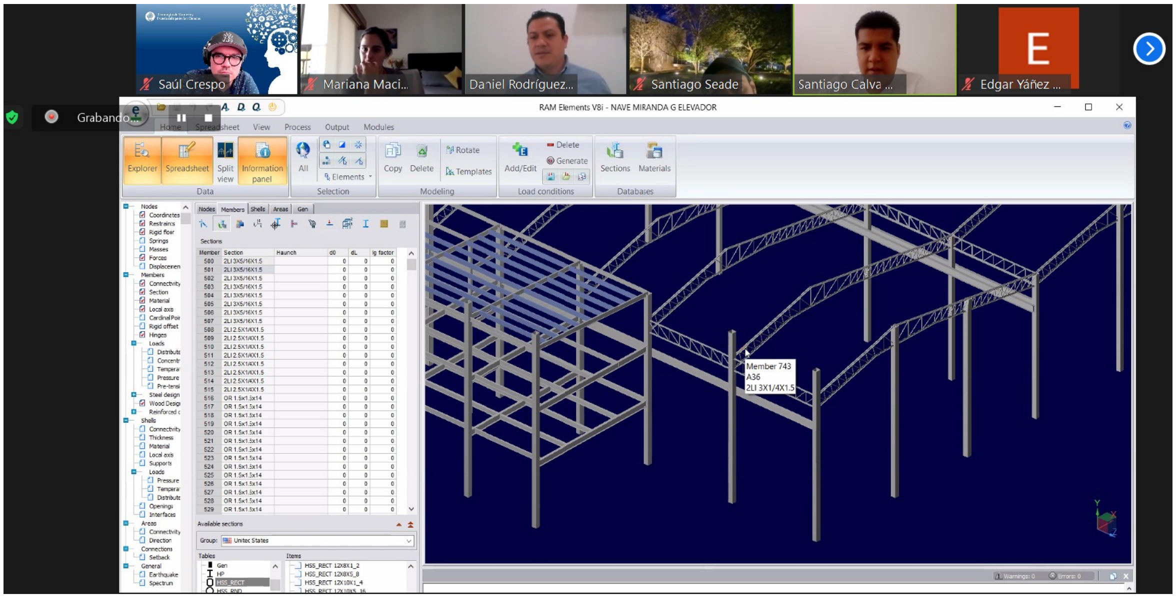

Fig. 5 Typical meeting with professional engineers from industry partners and the class.

The participation of the strategic parnerts did not limit only on marking the final projects but they also provided information that was relevant to the project such as examples of similar real projects that they have solved in the past, topographic conditions of the site in study and some comments of how they solved certain problems in this kind of projects. Fig. 6 shows some activities related to the solution of the Challenge and how the Strategic Industry partner can help with the experience as professional engineers they have in these topics.

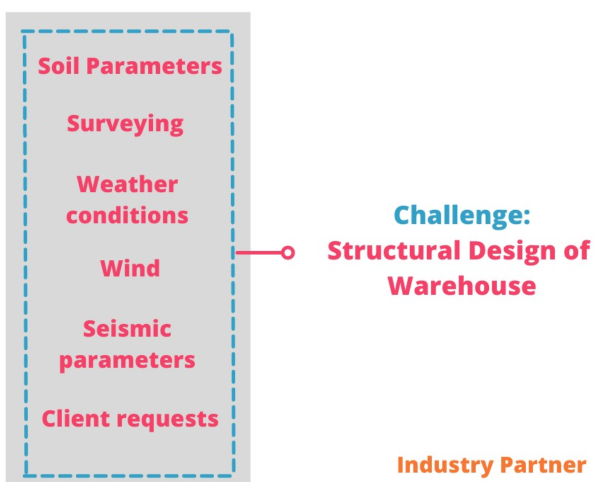

Fig. 6 Framework of Challenge

There were also some construction sites visits organized by the Strategic Partner. In this visit from some students, they could observe the physical characteristics of the soil, some sections and fills in the terrain as well as some access roads for a project similar to the one they were solving in the challenge. This kind of experience also enriched the challenge and gave the students a taste of the work of professional engineers on site. Fig. 7 shows some photographs of the visits.

Fig. 7 On-site visits.

From all the information students gathered in the meetings with the strategic industry partner and from the sessions with their professors and instructors, students worked in teams to get a solution to the challenge, analyzing different options for their proposal before deciding on a particular structural system.

During the stage of preparing several proposals for the structural system of an industrial warehouse, the participation of the industry partner, or strategic partner, was very important by providing feedback to students and some observations to their different proposals. With this information, students refined their solutions and improved their final solution. During this cycle of communication with the professional engineers, students also learned about some drawbacks of some structural systems for this kind of projects and the advantages of others. Fig. 8 shows some of the models or proposals for the roof of the warehouse, presented by the students during the process of the solution of the challenge.

Results and Analysis

In order to measure the impact of the participation of the industry partner and also to measure the students' satisfaction, a survey was designed with simple questions that students answered. The first question had to do with the perception of the students regarding the impact the challenge had in their learning process by boosting their interest in the contest of the course; 95% of students answered in an affirmative way. Only 5% did not consider that the challenge helped them be more interested in the course, as shown in Fig. 9.

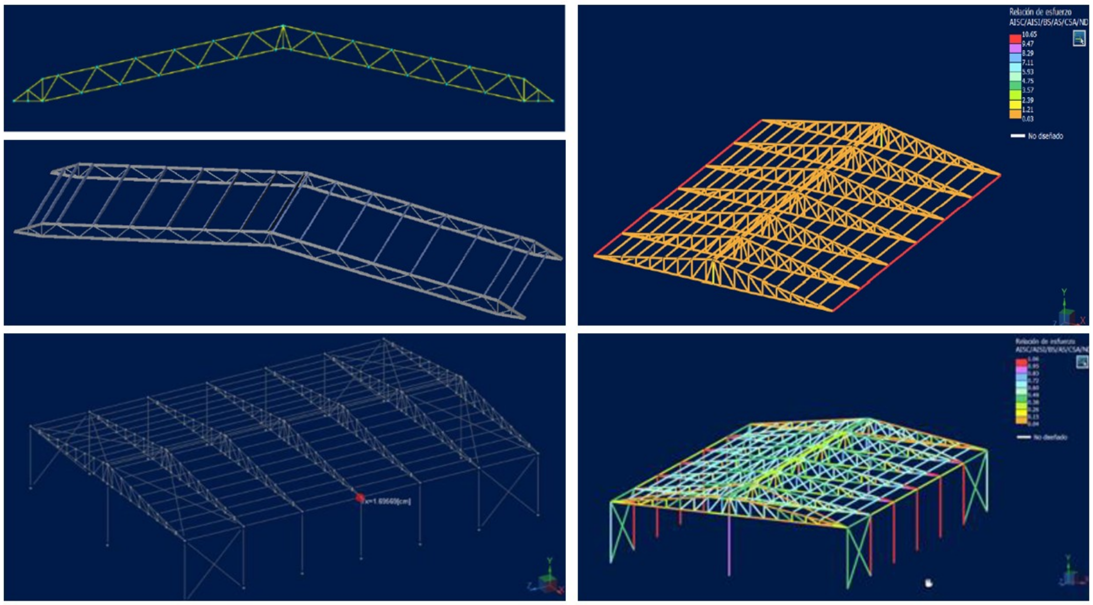

Fig. 8 Warehouse models

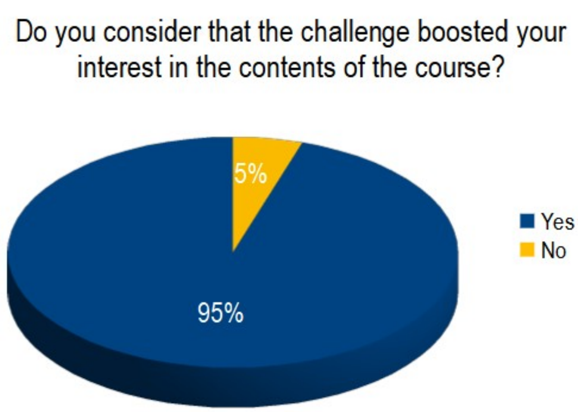

Fig. 9 Impact of the challenge in the motivation of students.

When students were asked about the importance of the challenge in their learning process for this course, in a scale from 1 (least important) to 5 (most important), 69% of students selected 5, 23% gave 4 as answer, 3% selected 3 and 5% opted for 2. There were no answers for 1, as it is shown in Fig. 10.

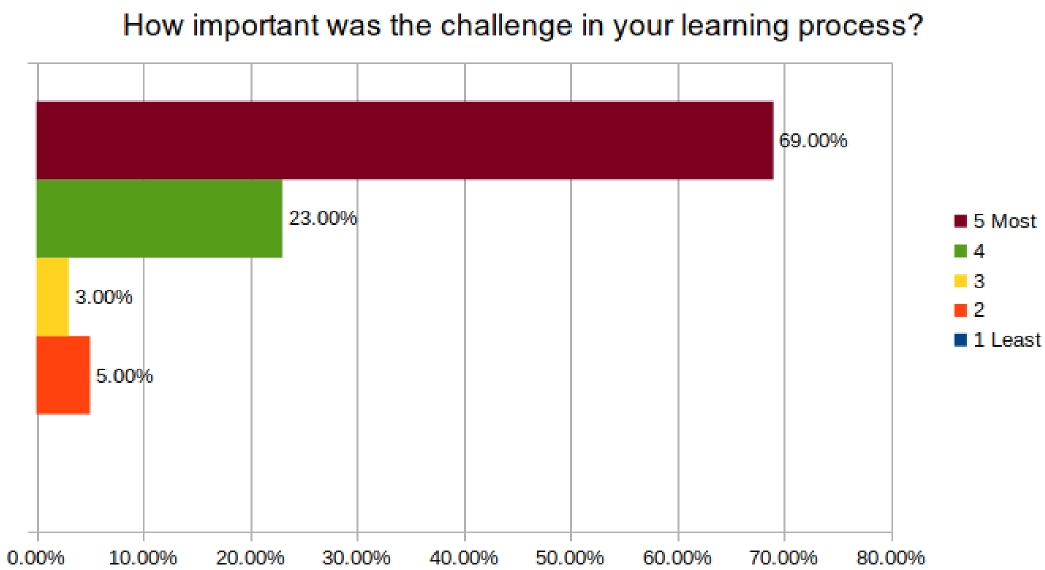

Fig. 10. Perception of students on the importance of the challenge in their learning process.

As it was previously mentioned, a very important element of our new educational model is the link between theory and practice, and it is for this reason that the participation of industry partner we consider it stratetegic. When students were asked if the participation of the industry partner had positively impacted their learning process and enriched the solution of the challenge, 90% answered "yes" and only 10% did not consider the participation of the strategic partner as a positive one. See Fig. 11 for these results.

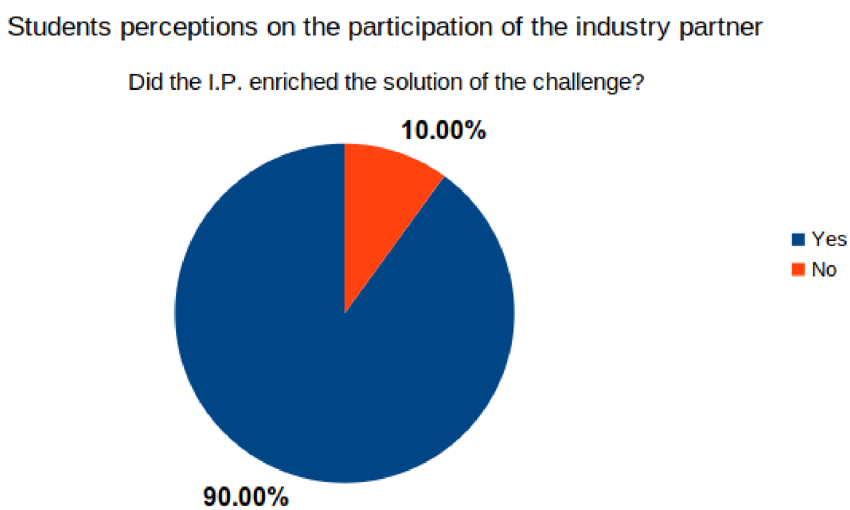

Fig. 11 Perception of students on the participation of the industry partner.

In Fig. 12 we can see the perception of students on the impact the industry partner had in their proposal of solution for the challenge. 75% of students think that the impact of the feedback and communications with the strategic industry partner had the maximum value, 15% marked it as 4 in a scale from 1 to 5; 5% marked 2 and 3 and there were no answers for 1.

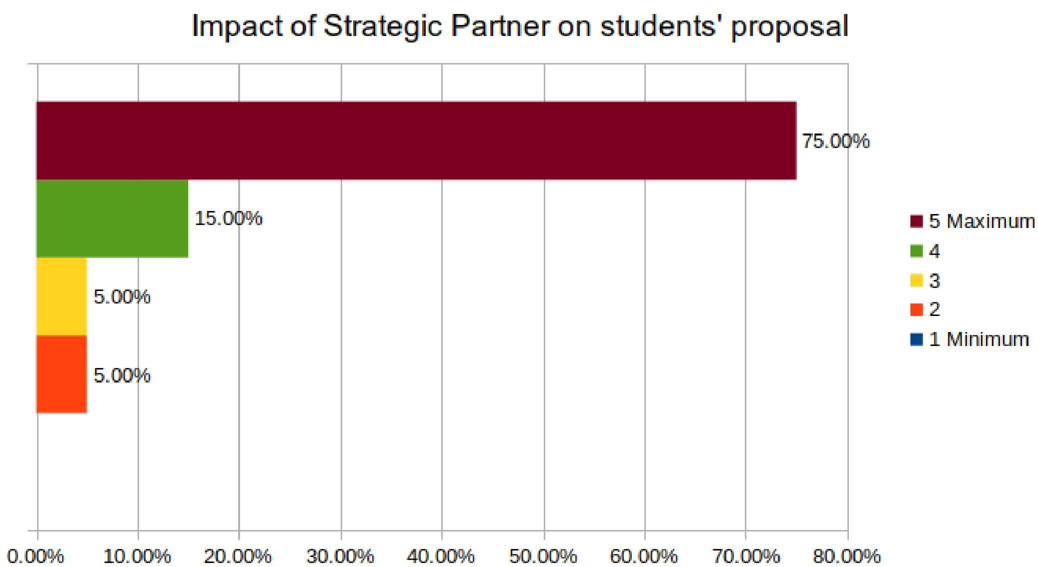

Fig. 12 Students' perception on the impact the strategic industry partner had on the challenge solution.

It is interesting to note that when students were asked about what their preference would be for a future strategic partner if given several options to choose from, 72% preferred a construction company specialized in steel structures, (see Fig. 13), and we consider that the construction site visits had to do with this choice and also, the feedback they received about the constructability of certain proposals, that is, they preferred real world applications and do not want to see only calculations or blue prints that they might get if they opt for an Engineering firm without those visits to construction sites.

Conclusions

In this course, the participation of a strategic industry partnet was crucial in the learning process of our students. In contrast with previous courses that cover the same topics of Structural Analysis with a traditional approach (lectures), in this course with a partner from industry, students got more motivation and applied the knowledge that was presented to them by professors, by solving a real case scenario that we call "the challenge" of the course. Feedback provided by the professional engineers from the strategic industry partner added value to the theory of structural analysis by including topics such as factibility of the project, constructability of the proposal, excess of workshop for the steel structures, difficulty of some connections on site, etc. From this communication with professional engineers, students enriched their solutions and modified their original proposals. The motivation in the students was high throughout the course and the fact that their solution was validated by professional engineers from industry gave them the sense of Engineering practice in the real world, not just in the classroom.

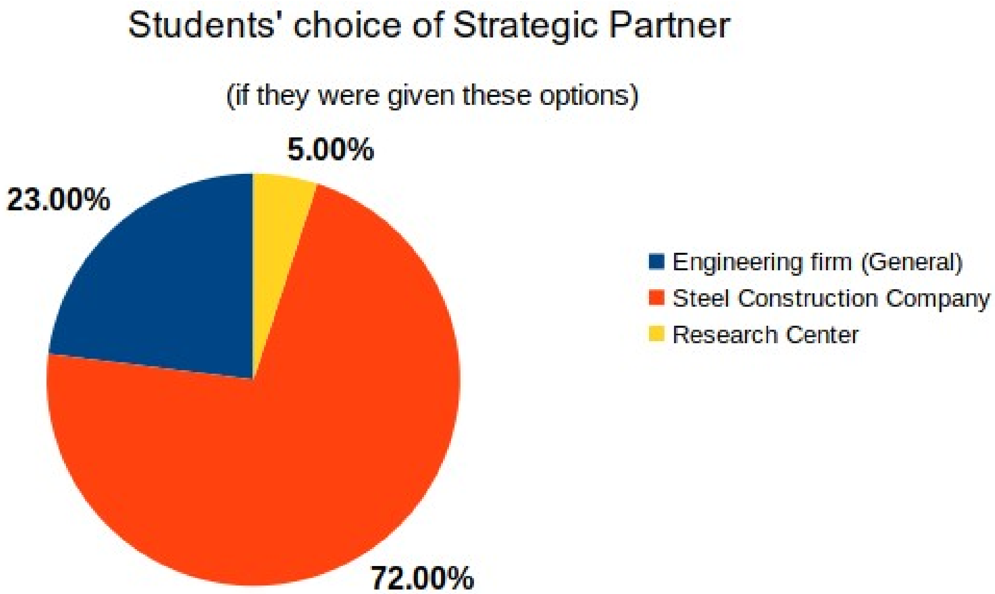

Fig. 13 Preference of the type of strategic partner students would like to see in coming courses.

The visits to construction sites of similar projects to the one presented in the challenge added other elements to the course such as preliminary work in the terrain, soil compaction, access roads and temporary material warehouses, among others. Another important aspect that students realized when they visited the project was the paperwork required to have a project running with all permits needed in advance as well as the safety and health measures for the personnel.

The model presented in this paper can be extended to other courses in which the participation of professionals from the industry can play an important role as formation partners or strategic partners for the university and professors/instructors, particularly for courses that sometimes are difficult for students to make a connection between theory and practice.

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