CHALLENGE-BASED LEARNING ENVIRONMENTS FOR THE DEVELOPMENT OF ENGINEERING SKILLS

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Abstract

Universities and employers are looking for innovative strategies to effectively develop -in future engineering professionals- the different types of skills declared by the Organisation for Economic Co-operation and Development, OECD, in its *Future of education and Skills 2030* project. One of the most important conclusions is that in a few years there will be particular types of work that will require competition in new skills that have not been part of the basic skill set of that occupation previously. One of the teaching strategies developed at the moment in several top ranked universities is the technique of challenge-based learning, combined with the new approaches of competencies-based evaluation frameworks. Many of these experiences may be unsuccessful due to the lack of flexibility of curricular programs, which requires the instruction to be carried out in environments limited to each course, without the intervention of external stakeholders as technicians and customers. Our project was based on the design, development and implementation of a university-industry collaboration in a challenge-based learning experience, with engineering students of different subjects and semesters. In this way, the designed approach favors: (i) the ability to transfer the knowledge acquired from one domain of specificity to another; and (ii) the competence of lifelong learning aptitude. The intensive interaction between academia and industry allowed the deployment of multiple real-life challenge solution strategies and the effective interaction with customers considering relevant factors from different perspectives. This *Work in Progress* study is being conducted based upon a qualitative design methodology. The assessment considers different evaluation instruments, including rubrics, checklists, observation guides, and exit surveys. The results obtained so far showed that the designed experience promoted a better understanding of scientific concepts in engineering subjects and a higher capability to develop cross-curricular skills.

Keywords: Active learning, Higher Education, Educational Innovation, University/Industry Collaboration.

1 INTRODUCTION

Challenge-Based Learning is based on the theories of Experiential Learning, whose fundamental principle is that students learn better when they actively participate in open learning experiences, than when they passively participate in activities led by an instructor or in conferences taught by teachers. The implementation of Challenge Based Learning in higher education curricula allows students to apply what they learn in real situations, face complex problems, design and test creative solutions; and most importantly: interact with other students to develop skills and abilities as a team.

Modern educational models must allow students to become leaders capable of facing challenges and opportunities in the 21st century and, to be successful, seek to improve competitiveness by developing the required skills and abilities in various professional fields. These skills are fundamental to face the challenges and, in turn, must become cross-cutting issues, such as critical thinking, understood as a tool to evaluate information and ideas and solve complex problems in non-routine ways. The importance of soft skills in engineering, especially Critical Thinking and Creativity, has been studied for many years by academic researchers. However, it has not been until very recently, since freshmen belong almost 100% to Generation Z, that the need has been seen to introduce innovative approaches so that these competences are developed in an effective and lasting way considering the particular characteristics of *Gen Z engineers* [1]. Both, employers and international accreditation agencies, are the most interested in these competences being formally considered in engineering programs.

2 CHALLENGE-BASED LEARNING THEORY

Some of the essential conditions to promote an effective experiential learning in a Challenge Based Learning experience are [4]:

• Learning experiences should include reflection, critical analysis and synthesis activities.
• Learning experiences should be structured in a way that promotes students decision-making and responsibility for results.
•Students must participate actively and creatively in the approach and solution of problem.
• Experience must involve all participants not only intellectually but also emotionally and socially.
• Instructor and students can experience success, failure, uncertainty and taking risks, because the results of the experience may not be totally predictable.
•The instructor recognizes and promotes opportunities spontaneous learning
• Instructor has among its functions the problem statement, establishment of limits, facilitate the learning process, support students as well as the physical and emotional integrity assurance of the students.
• Learning outcomes are personal and are the basis of experience and future learning.
• Experience should promote student self-awareness, empathy with their peers and greater knowledge of the environment and other cultures.

Challenge-based Learning is an approach of the andragogy that has been successfully incorporated into engineering study programs because it achieves a real-world perspective and considers that student learning involves "doing" regarding a subject of study. This approach offers a student-centered learning framework that emulates real work experiences in industry and corporations: Challenge-Based Learning takes advantage of students' interest in giving practical meaning to education, while developing key competencies noted by international organizations: Leadership and social influence; Emotional intelligence; Reasoning, problem-solving and ideation; and System analysis and evaluation. In their latest reports, both, the Organization for Economic Co-operation and Development, OECD, and the World Economic Forum, WEF, introduced a comparison of today's skills with those demanded of future professionals to face the challenges of the Fourth Industrial Revolution [2,3]. Table 1 shows the skills expected to be trending by 2022.

Table 1. World Economic Forum report [2]
Increasing skill demand (2022)

1	Analytical thinking and innovation
2	Active learning and learning strategies
3	Creativity, originality, and initiative
4	Technology design and programming
5	Critical thinking and analysis
6	Complex problem-solving
7	Leadership and social influence
8	Emotional intelligence
9	Reasoning, problem-solving and ideation
10	System analysis and evaluation

3 STAKEHOLDERS

This *Work in Progress* project involves various stakeholders including professors from the Tecnológico de Monterrey Engineering Department and Mexican energy efficiency and digitization start-up S2G Energy. The project delivered as a result the *Electric Energy Efficiency Management and Monitoring* learning experience which will be addressed in the following paragraphs. During the activity, students had the opportunity to live first-handedly the experience of providing an energy management service to real customer sites run by an international restaurant chain, under the tutoring of their professors and team members from S2G Energy.

3.1 Tecnologico de Monterrey

3.1.1 Semana i as an institutional approach to Challenge-Based Learning

Activities carried out during the Semana i period are intended to allow students to interact directly with real industry needs which are not typically approached in traditional lecture environments. While Semana i activities in the Engineering Department are aimed to develop the technical abilities required to solve problems in real industries, students also engage in activities demanding soft skills such as leadership, teamwork and communication.

Leadership. Leadership allows students to exert influence in the groups and organizations to which they will belong in the future, thereby increasing the possibility of impacting their development and ascending to strategic or directive positions.

> Leadership indicators assessed during *Semana i*: The leader listens to the opinions or suggestions of the group members and considers them in decision making; The leader promotes the development of his/her followers, assigning them functions and creating opportunities for their growth; The leader has a broad vision of the group and the national and international environment.

Teamwork. The collaborative work will allow students to integrate effectively in a group achieving positive interpersonal relationships and directing their efforts towards the achievement of common goals which will result in high efficiency and productivity of the team.

> Teamwork indicators assessed during *Semana i*: Student considers the views of their peers in the performance of tasks and provide and accept effective feedback; Student participates in each of the phases of the group work and ensure that the final product or task meets all the requested requirements and is delivered with quality and in a timely manner; Student fulfills in an efficient and timely manner the roles and tasks assigned to him/her within the group.

Communication. Good communication allows the student to understand the messages or ideas of others and convey their own clearly and precisely, which favors the assertion of arguments and the generation of positive collaborative environments necessary to achieve professional goals.

> Communication indicators assessed during *Semana i*: Student communicates in a precise and organized way the information that he/she wishes to transmit, either orally or in writing, considering the objective he/she pursues and the characteristics of the person or group to whom it is addressed; Student applies current academic standards for the use of oral and written language; Student uses the appropriate supports and means to effectively present the information he/she shares.

3.2 S2G Energy

S2G Energy provides Digital Energy Efficiency services to Enterprises in Mexico and internationally. With the aim to boost profitability in our customers, we enable resources usage optimization in their operations (mainly electricity, gas, water and heat), by delivering an AI-People powered decision making process from the front line of the operations up to the C-Suite of the organization. The service typically encompasses four key pillars: I) Digitization through IoT sensing technology, II) Data integration both from sensors, processes and other key variables, III) Analytics powered by specific business needs and machine learning, IV) Actionable information that speaks our customers' business language. The resulting value is characterized by bottom line financial performance, an information empowered organization driving operational discipline and control, overall energy intensity improvement, data driven decision making and a lower carbon footprint in a typically high energy user.

Our structure of work is defined within the concept Energy Management as a Service (EMaaS). We start from the assessment in which, in conjunction with our customers, specific business needs are identified, then the scope definition to calibrate the optimal level of digitization, up to the deployment of sensors (if required) and the completion of the set-up required for the Analytics process. After the platform is ready, the service period starts and lasts typically 2 to 3 years. Within the service contract results, performance clauses, training, change management plan, and many others are established in order to yield the results and the Digital transformation in our customers' organization. Our team is diverse in every sense, most of us with an engineering background, but with strong capabilities on the analytics, communication, facilitation, software development, also with a passion to create things from zero by leveraging on the latest technology and knowledge available. We typically spot talent for character and their commitment to leave a better world behind by being persistent, hungry, driven and curious.

4 ACTIVITY DESCRIPTION AND METHODOLOGY

4.1 Description of the learning experience

The *Electric Energy Efficiency Management and Monitoring* experience was included in the Semana i activity offer of 2nd term 2019, in collaboration with industry expert S2G Energy. It was designed for third and fourth-year students of the Sustainable Development Engineering undergraduate program at Tecnológico de Monterrey Campus Santa Fe. Students from different semesters were grouped into two different teams to perform the activity, which was divided into the four stages described in Fig. 1:

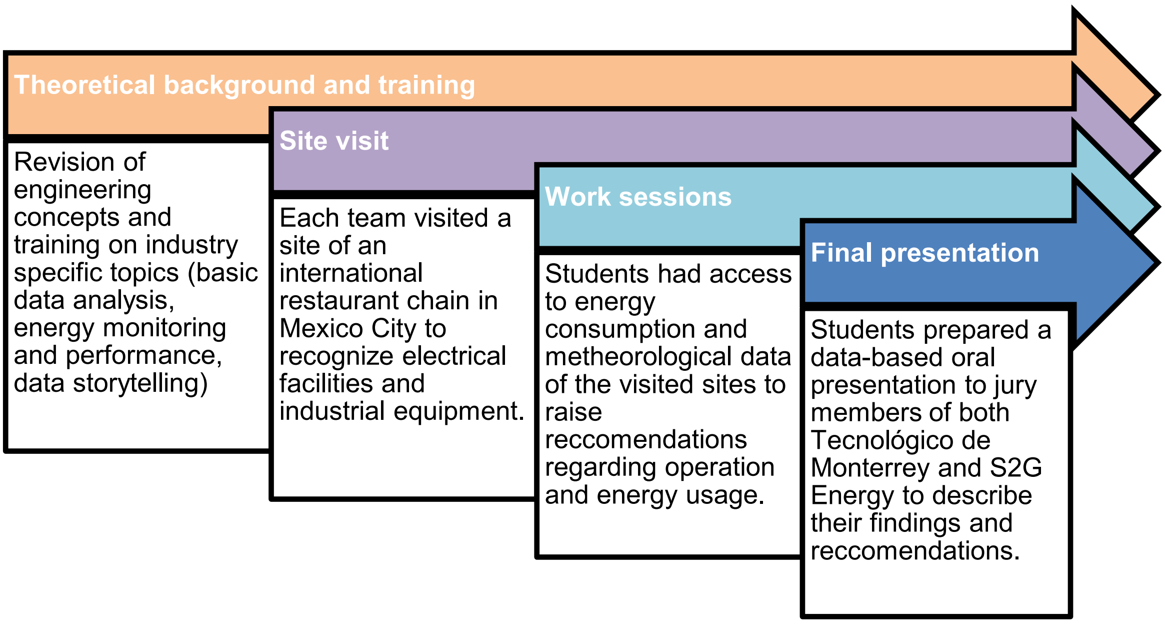

Fig. 1: Stages of the *Electric Energy Efficiency Management and Monitoring* learning experience

This challenge-based learning project put the students in direct contact with industry participants to address energy necessities of a real customer, allowing them to become familiar with concepts and activities that would be relegated to a secondary plane, if not completely omitted, in a traditional lecture learning environment. Such activities include the delivery of preliminary energy diagnoses, recognition of industrial equipment in real electrical facilities and data analysis for energy efficiency, involving preliminary correlations with business operation variables such as site occupation, operations scheduling, local weather conditions and geographical location of the sites. The site visits also helped students become familiar with operation protocols specific to the client. Furthermore, soft skills such as teamwork and leadership were developed, as students were required to work in teams, not necessarily with peers from their same semesters. Students were required to present their findings and data-based recommendations in a final exposition to jury members from both S2G Energy and Tecnológico de Monterrey, which helped further develop the communication skills required in a real industry context.

4.2 Educational methodology

The methodological design includes the following components [3]:

Challenge-based learning approach. Confront students with a relevant and open problem situation, for which a real solution is demanded.

Methodological process. Students analyze, design, develop and execute the best solution to address the challenge in a way that they and others can see and measure it.

Outcomes. Students are required to create a solution that results in a concrete action.

Role of the professor. Coach, co-researcher and designer.

Instruments. One of the crucial aspects of Challenge Based Learning is related to evaluation. Although in general terms, this pedagogical approach does not have a unified evaluation method, it is possible to identify common strategies used by teachers to assess the processes and products of the solutions implemented, as well as to provide feedback to each one of the phases involved in the students' learning experience. The evaluation of work by professors and students should consider two types of evaluation strategies: formative (occurs continuously during the whole process, guiding and facilitating learning) and summative (values progress in key points or at the end of the process).

5 RELATION OF DEVELOPED SKILLS WITH REAL INDUSTRY NECESSITIES

The project herein described aimed to help students develop the skills required in a real industry environment as perceived by a real technology-based start-up such as S2G Energy. While further evaluations to assess the level of development of each of such skills need to be enforced in future iterations of the activity, students were encouraged to put to practice specific skills which can be related to the talent necessities of the industry expert. Such necessities are listed and related to the *Electric Energy Efficiency Management and Monitoring* experience in Table 2.

Table 2. Industry specific required skills relation to the *Electric Energy Efficiency Management and Monitoring* learning experience

	Industry specific required skill	*Relation to the learning experience*
1	Capabilities on the analytics, communication, facilitation and software development.	Students were encouraged to select the best software alternative and data analysis tool to deliver the expected result as a part of the activity.
2	Create things from zero by leveraging on the latest technology and knowledge available	While the data was given to the students in a raw format, the participants were successful to deliver a data-based presentation with specific recommendations made to a commercial customer, even under the time and information limitations inherent to the format of the activity.
3	Commitment to leave a better world behind by being persistent, hungry, driven and curious	The students had to act in a curious, autonomous way to achieve the desired result in a context of limited information and uncertainty on the outcome.

6 CONCLUSIONS

The *Electric Energy Efficiency Management and Monitoring* learning experience, designed under the Challenge-Based Learning framework, led to successful results in the development and practice of industry specific skills as listed by the industry expert participating in this project. The results obtained so far showed that the designed experience promoted a better understanding of scientific concepts in engineering subjects and a higher capability to develop cross-curricular skills, along with soft skills such as teamwork, leadership and communication. Future iterations of the activity must enforce further evaluation and quantitative assessment of such skills.

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