Sustainability in the Professional Practice of an Engineer

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Abstracts

To meet modern society's demands, highly qualified professionals are driving the reformulation of the teaching-learning model in universities. The framework of the Tec21, the Educative Model of the Tecnologico de Monterrey, provides the focus over the training programs on the relationship between the student and the environment for the development of personal and professional competencies through the resolution of challenges linked to real-world scenarios. In this work, we present information about a challenging experiential activity for students with an undergraduate professional curriculum. The core elements were a soap company, a higher education institution (Tecnologico de Monterrey), and the federal government (Mexico); it was consistent with specific problems to be solved in the soap company in Mexico by inserting students in it. Based on the framework of the experiential study of the company, constitution and characterization of the processes, in individual surveys, students recognized a better learning in a real context, and they recognized that the importance of the challenging activity through ten indicators and that this exercise contributed to the development of transversal competencies: co-responsibility, social responsibility, and sustainability. These results reinforce the importance of the development of transversal competencies in the training of professionals.

Keywords: Challenge-Based Learning, Educational Innovation, Higher Education, Sustainability, TEC21 Educative Model.

Introduction

Due to globalization's worldwide panorama and the demand for better articulation and congruence between work environments and the educational environment, professional preparation demands a more profound development of skills and the reformulation of professional programs and syllabi in universities. Such programs must consider improving the

human condition, creating value, and prospering in terms of sustainability [1]. That is, to contribute a more inclusive development and to engage with urgent issues related to sustainability, now described in the Sustainable Development Goals (SDGs), it is essential to train professionals who integrate into society as change-makers in matters of sustainability [2]

Through an efficient and effective collaboration of all stakeholders in society, business efforts [3] have been translated into principles aimed at establishing actions that allow all to produce greater efficiency in processes [4], [5]. Given the need to solve new and current prevalent problems, education must cover the required elements [6], [7]. These are learning to learn, learning to do, learning to live together, and learning to be through teaching systems that are contextualized in reality [8] so that there is not only the mastery of technical knowledge but also the development of strategic competencies like critical thinking, collaborative work (teamwork), and cognitive flexibility [9]. In this way, the preparation of the professional involves, in addition to the integration of knowledge, willingness to continuous learning [10], improved performance, interactions, and reflection about the making of decisions [11].

With this vision, Challenge-Based Learning (CBL) is a useful strategy for developing these competencies. CBL is based on an educational trend of experiential learning, which entails the student's doing or acting regarding a topic of study from a real-world perspective [12]. This learning strategy, incorporated into areas of study such as science and engineering [13], [14], allows the student to be presented with defined challenges such as activities, tasks, or situations implying a stimulus and a challenge to be carried out. Facing problems, the student learns new ideas and tools, applies these to the problem solution, and gets interested in finding solutions and more problems to solve [15]. The administration of knowledge through learning modules to support the resolution of problems, the reflection and performance feedback, as well as the recording of results obtained (pointing towards a future improvement process) are relevant in this strategy.

In this context, the framework of the Tec21 Educative Model of the Tecnologico de Monterrey [16] provides the training of professionals who face new paradigms, advances, and multiple transitions in their performances and social interactions in the context of CBL. The training programs focus on the student's relationship with the environment for the development of disciplinary and transversal competencies [17] through the resolution of challenges linked to real-world scenarios [15]. For this reason, the present project proposes implementing a challenging experience through the insertion of students in a company to solve specific problems and encourage key transversal competencies at the same time, highlighting sustainability and evaluating itself from the participants´ perspective.

Description of the innovation and the methodology

Based on the guidelines of the Tec21 Educational Model which addresses the need to develop disciplinary and transversal competencies during the integral training of the student [17], a new learning experience for the students in this study was designed. The teaching differed from the traditional format by developing a challenging activity to help a private sector company. Undergraduate students from the third to seventh semesters of engineering, social studies, and

business schools in the Tecnologico de Monterrey system were immersed in the company and the challenge to learn, live, and participate actively.

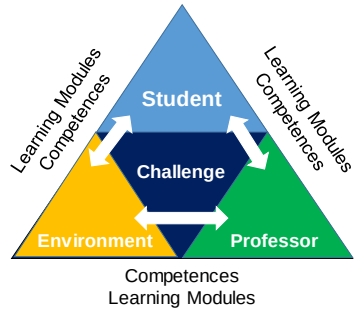

Figure 1: Pillars of Tec 21 Educational Model.

The activity was carried out during an institutional initiative called, “i-Week”, which took place on October in 2016 (23 students), 2017 (26 students), 2018 (19 students), 2019 (30 students), 2021 (20 students) y 2022 (9 students).

Before this, a guiding collaborative group composed of faculty from the Engineering School, personnel of the La Corona Soap Factory, and federal government staff from the Federal Bureau for the Protection of the Environment (PROFEPA in spanish) was established. The soap company contributed with spaces for interaction, technological tools and participation of divisions such as Quality Control, Production, and others. The government staff plunged into the normative framework of regulations and certification, which was ratified by an accredited consultant.

The proposed modularization of the learning process is shown in Figure 2, where the students were given the theoretical and practical bases to be integrated and applied for the development of alternative solutions to diverse problematics, which may be focused on the following thematics:

- Inconsistencies in the National Water Law
- The viability of alternative fuel usage,
- Wastewater discharges treatment,
- Definition of optimal operative parameters for the product, and emergency responses.
- Design and development of a sustainable product.
- Reduction of the risk to workers' occupational health.

Each challenge was assigned to a multidisciplinary work team of 3 to 5 students, specifying a collaborative learning environment. The students had to prepare a presentation by teams at the end of week one, indicating the solution to the problem and its fundamentation.

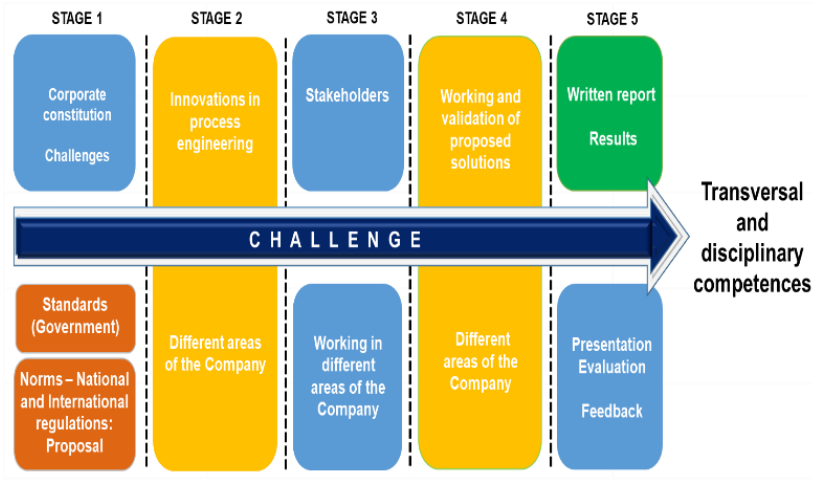

Figure 2: Modularization of learning in the experiential challenging activity indicating in color the main actor in each activity: blue (students), orange (company), yellow (environment) and green (professor).

Several technological tools supported the process. These included Blackboard (Bb) or Canvas, Kahoot, Mentimeter, Excel, and the student satisfaction survey, which is an online survey performed with 10 indicators (satisfaction, recommendation, activity level, collaboration, knowledge meaning. The latter was used to assess the opinion of the students regarding several indicators (satisfaction, recommendation, activity level, collaboration, knowledge meaning, learning significance, methodology, commitment, novel concepts acquisition, process mentoring, evaluation and expected performance) using a ten-point Likert scale, where 1was completely disagreeing, and 10 was completely agreeing, this was applied through the informatic and institutional system at Tecnologico de Monterrey. To measure what competencies the students benefitted from the challenging activity a second survey was applied, using a five-point Likert scale [18], where they chose 1 if they completely disagreed that the competence was developed, and 5 if they were completely agreed that the competence was achieved.

Once the experiential challenging activity finished, the institutional and secondary survey data were reviewed, and descriptive statistics were performed.

Results and discussion

Based on the results obtained from the student satisfaction survey (Figure 3), it was found that the educative, Challenge-Based Learning strategy and its articulation during the i Week facilitated the deployment of the experience throughout the company's framework. As observed, the student scored with more than 8 points in the 10 indicators, which indicated that the students agreed with the majority of these in a satisfactory way. The core elements were the role of the professors as mentors advising and following the students' progress through the training process;

the company-academy-government collaboration to present the different areas of activity, and the relevance of the business challenges presented. This work confirmed the effectiveness of planning the contents (the learning and practice modules) to direct the proposed solutions to the company's real problems and achieve meaningful learning through the real-world experience.

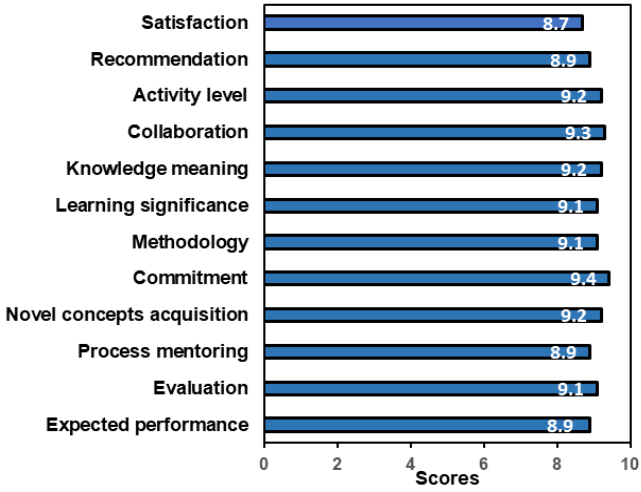

Figure 3: Obtained scores for the 10 indicators in the student satisfaction survey for the applied experiential challenging activity.

Based on the framework of the experiential study of the company about the quality and self-sufficiency of its systems, the competitiveness of its products, and its services at the local and international levels, the individual surveys (Figure 4) yielded the following results: The students recognized improved learning of business competencies in a real context (33%), and they distinguished relevant aspects such as business vision (33%), co-responsibility (72%), social responsibility (56%), and principles of sustainability (56%).

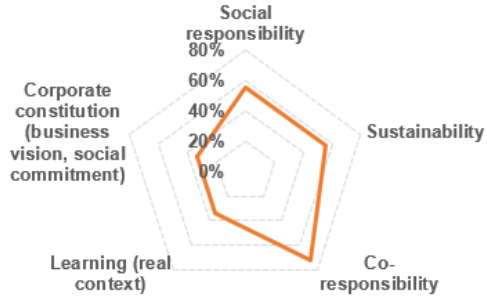

Figure 4: Frequency of students answers with respect to the competencies developed during the activity.

As indicated in the results, more than 50 % of the students mentioned that the activity helped to develop their competence of sustainability since they expressed in commentaries that this activity encouraged them to be more conscious that the solution impacts to the environment and society and at the same time that the activity was applicable to several professions in engineering. They valued the scenery of the challenging activity was real and professional, outside of the traditional learning in the classroom. Recently, this positive relationship between sustainability competence and the satisfaction degree of undergraduated students has been reported in some works, particularly in social sciences but not in engineering students. For example, business students perceived as "good" the incorporation of sustainability in their practices [19]. In a recent work involving a spanish business school, it was found that the adoption of sustainability practices increased student satisfaction because this promoted their internationalization and therefore their competitiveness [20].

Analyzed together, the results of the polls and observations drew the following findings:

- Students found themselves at the same level of learning and skills development with more open, organized, and systemic behavior.
- The acquisition of knowledge through learning modules adapted to live experiences strengthened the analyses of production principles and strategies.
- When faced with real-world problems, the students were interested and participated actively and reflectively. They were enabled to make informed decisions considering environmental impacts and limitations, economic viability, integrated community, and their relationship.
- In addition to consolidating competencies for graduation, the challenge-based learning methodology strengthened and reinforced transversal competencies such as solving ethical problems, promoting feelings of citizenship and human empathy, and developing oral and written communication skills.
- The use of the Blackboard and Canvas platforms facilitated interactions and asynchronous communication between the training group and the leaders, helping to manage the activity, consult about materials and documents, record learning outcomes, and generate work portfolios for the base teams.

Similar results on reinforcing these competencies have been obtained with other educational innovations within the framework of the Tec21 Educational Model, such as the i-Semester [13].

The partnership of the private-sector company, the government, and academia as a guiding axis exhorts top-level commitment to objectives clearly stated and understood by all the parties. The technological resources for communication and evaluation of processes are necessary and fundamental. These certify the strengthening of professional competencies and provide the means for feedback and reflection.

Conclusions

Developing transversal competencies in engineering undergraduates is fundamental for fulfilling the labor demands of the current world. In the present work, a collaborative group of three entities (Faculty, a private company, and government) encouraged undergraduate engineering students to solve real-world problems in the context of CBL. The outcomes of the satisfaction survey indicated that the students recognized with major impact the development of the transversal competences: co-responsibility, social responsibility, and sustainability. As discussed previously, similar results on the reinforcement of these competencies have been found in other educational innovations within the framework of the Tec21 Educational Model. The execution of the experiential challenges within the CBL approach and its deployment with the resource known as i-Week provided a context and a differentiating space that implied stimulus and motivation for the students. The students recognized that this teaching/learning methodology them and contributes to their professional performance by developing transversal competencies, which they cannot experience and acquire in the traditional classroom-teaching system.

Educational systems should favor this type of integral teaching practice in real contexts to inculcate professionals with the technical capability to solve problems and promote values and attitudes expressed in principles of development and well-being (transversal competencies). The present strategy may be applied to other undergraduate programs and professions.

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WORKS CITED

OCDE. “Diagnóstico de la OCDE sobre la estrategia de competencias, destrezas y habilidades de México”. Ediciones OCDE, 2017.

Vázquez-Villegas, P., Geny Molina-Solis, E., Alberto Mejía-Manzano, L., Romo-Molina, J., & Membrillo-Hernández, J. (2024). Creating Sustainable Competencies in Engineering Through Biomimetics Courses. International Journal of Engineering Pedagogy, 14(3).

Naciones Unidas. “El futuro que queremos.” Resolución aprobada por la Asamblea General el 27 de julio de 2012, 66/288, 2012.

J. Iles, (2015). “Circular Economy-The forgotten low-carbon vector.” Circulate, 2015. http://circulatenews.org/2015/12/circular-economy-the-forgotten-low-carbon-vector/

R. Lozano, “Towards better embedding sustainability into companies´ systems: an analysis of voluntary corporate initiatives.” Journal of Cleaner Production, 25, pp. 14 – 26, 2012.

UNESCO. “Educación y evaluación por competencias: un desafío para el Laboratorio Latinoamericano de Evaluación de la Calidad”. Oficina Regional de Educación de la UNESCO para América Latina y el Caribe, 2020. Obtenida el 3 de junio de 2023 de www.unesco.org

UNESCO. “Reimaginar juntos nuestros futuros: un nuevo contrato social para la educación”. Informe de la Comisión Internacional sobre los Futuros de la educación, 2022. Obtenida el 12 de junio de 2023, https://unesdoc.unesco.org/ark:/48223/pf0000381560.

J. Delors, “La educación encierra un tesoro: Informe para la UNESCO de la Comisión Internacional sobre la Educación para el siglo XXI.” México: Ediciones UNESCO, 1996.

A. Gray, “The 10 skills you need to thrive in the Fourth Industrial Revolution.” World Economic Forum. Retrieved from http://www.weforum.org, 2016.

K. Fuertes, A. García, “Aprendizaje a lo largo de la vida. (Reporte EduTrends, junio). Observatorio, Instituto para el Futuro de la Educación, Tecnológico de Monterrey, 2023.
P. Aznar, and M. Ull, “La formación de competencias básicas para el desarrollo sostenible: el papel de la Universidad.” Revista de Educación, número extraordinario, July 2009.
Gallagher, S. E., & Savage, T. (2023). Challenge-based learning in higher education: an exploratory literature review. Teaching in Higher Education, 28(6), 1135-1157.
I. Abud, A. Sandoval, A. Solares, F. Sandoval, Palafox, J. Rodríguez, G. Flores, “Improving learning outcomes in industrial engineering students with challenge-based learning.” ICERI. 2017. http://www.oei.es/cienciayuniversidad/spip.php?article479.
Doulougeri, K., Vermunt, J. D., Bombaerts, G., & Bots, M. (2024). Challenge-based learning implementation in engineering education: A systematic literature review. Journal of Engineering Education.
J. Escamilla, E. Quintero, E. Venegas, K. Fuerte, K. Fernández, y R. Román, “Aprendizaje Basado en Retos.” (EduTrends Report, October). Observatorio de Innovación Educativa del Tecnológico de Monterrey, 2015.
Tecnológico de Monterrey. Modelo Educativo TEC21. Tecnológico de Monterrey, Vicerrectoría Académica, 2016. http://www.itesm.mx/va/modeloeducativo/
J. Escamilla, B. Calleja, E. Villalba, E. Quintero, E. Venegas, K. Fuerte, R. Román, y Z. Madrigal, Educación “Basada en Competencias.” (EduTrends Report, February). Observatorio de Innovación Educativa del Tecnológico de Monterrey, 2015.
Johnson, R. L., & Morgan, G. B. (2016). Survey scales: A guide to development, analysis, and reporting. Guilford Publications.
Sharma, U., & Kelly, M. (2014). Students’ perceptions of education for sustainable development in the accounting and business curriculum at a business school in New Zealand. Meditari Accountancy Research, 22(2), 130-148.
Bagur-Femenias, L., Llach, J., Benito, Ò. E., & Fabregà, M. B. (2023). Sustainability practices and student satisfaction in business schools: the role of notoriety and internationalization. Intangible Capital, 19(2), 131-145.