Incentivizing Continuous Learning to Master New Skills and Knowledge in Engineering Undergraduate Students: Collaboration Strategy and Performance Assessment

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Abstract

The current Educational Model of the Tecnologico de Monterrey frames teaching-learning strategies that ensure the development of competencies at the end of the student's professional training process. These competencies are key elements to perform and adapt head on work and social scenarios currently unforeseen. On this line, the present work integrates results of an experience at a specific level, which promoted the development of transversal competencies according to the expected attributes to crown the graduation profile in engineering. With emphasis on the knowledge-skills guiding axis, an activity was designed collegially, requiring addressing content, solving a real problem, and integrating a performance evaluation system to manage one's own learning. The deployment involved active learning strategy linked to a collaborative work system. The essential elements of the methodology were the definition of roles, the setting of common objectives, teamwork and its processing, as well as recognizing and generating a positive interdependence with a high level of responsibility and commitment on the part of the student. The obtained results were: approximate a global process developing activities typical of professional practice; confirm the degree of progress in skills such as problem solving, evaluation of components and own reasoning; and evaluate and provide feedback on the process to project it into equivalent scenarios.

Keywords: *Higher education, Lifelong learning, Active Learning, Collaboration, Transversal Competencies, Student performance*

1. Introduction

The accelerated growth of today's societies demands the inclusion of professionals who solve complex problems and drive progress and transformation towards a common good [1]. Thus, an unavoidable change in training processes is expected from education that privileges the development of strategic competencies and, in turn, promotes reflection on the need to sustain the development of professional and personal competencies, it is to say, encourages lifelong learning [2]. Under this premise, in the Educational Model of the Tecnologico de Monterrey, which is based on competencies [3], strategies and training experiences contextualized in a reality for ensuring, the capacity to act in the face of challenges of a changing and uncertain world, we performed an opportune intervention for foresting lifelong learning framed on the active learning linked to a collaborative work system with engineering students enrolled in the first year of the exploration stage, 2022 – 2023.

2. Development

2.1 Theoretical framework

In today's societies, there are great challenges to create value and prosper, in order to achieve the well-being of people [4], which shows the need for greater collaboration among actors, distinguishing their different development and leadership capacities [5]. Regarding the insertion of professionals with a greater capacity for action, adaptation, interaction and reflection for decision-making [76, it entails a significant condition of comprehensive training contextualized in real experiences and under the framework of learning to learn, learning to do, learning to live together and learning to be [7]. Therefore, it is essential to distinguish vital functions of responsibility, leadership and resilience, both at the individual and community level, that is, with individual capacities and social competencies [8].
Lifelong learning is a broad term that refers to continuous learning throughout a person's life. Organizations like the European Commission, UNESCO, and the OECD agree that it involves the ongoing development of knowledge, skills, and competencies [19]. A literature analysis allows to identify

the skills that are considered for lifelong learning, these may be classified as cognitive, meta-cognitive and social-emotional skills. The first group contemplates problem solving, critical thinking, information literacy and research skills; the second group has self-direction and lifelong learning orientation, reflection, learning regulation and planning (stepwise processing, self-testing), learning management; and the third group are teamwork and collaboration, oral and written communication, empathy and personal agency, networking and social support [10, 11, 12, 13, 14]. Particularly, in engineering students, the development of lifelong learning skills acquires essential importance due to rapid technological change, globalization, and evolving labor market demands. Studies have already emphasized that engineering graduates must develop not only technical expertise but also transferable skills [15,16]. Literature research on the topic since 2019 focuses on the idea that lifelong learning enables engineering students to continuously improve their competencies, update their knowledge, and remain professionally relevant throughout their careers [17]. Under this panorama, it is undeniable that higher education institutions have a fundamental role in the integration of experiences for the formation of those skills and in preparing them to adapt to future challenges.The framework of the Tec21 Educational Model of the Tecnológico de Monterrey (MTec21) defines for its students the development of transversal and disciplinary competencies for their comprehensive training (**Figure 1**); these transversal competencies relate the student to their environment [189].
The present work was based on challenge-based learning (CBL) and collaborative work (CL), integrating a performance evaluation system to manage one's own learning [19, 20].

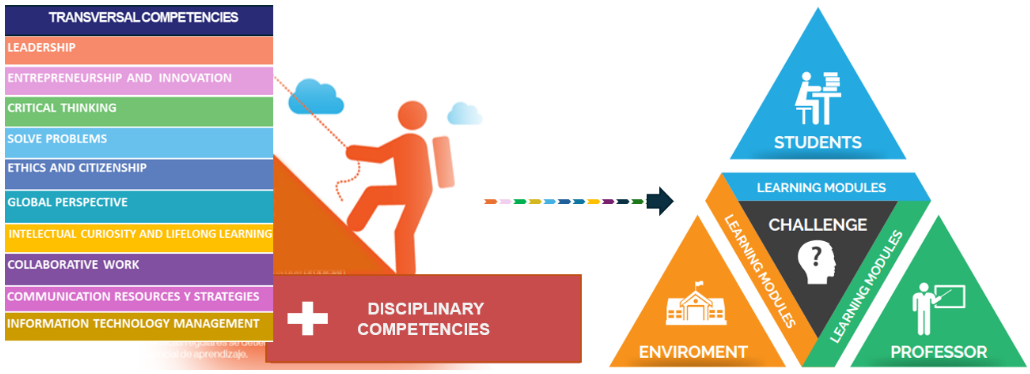

Fig. 1. Main transversal competencies and their linking to disciplinary competences in Tec21 Model

For the development of these competencies, four methodological actions are planned that allow the development of competencies to be organized and put into practice according to the level and moment in which the student is:

1. Analyze the competencies and their impact with other competencies in the study plan;
2. Plan and coordinate the development of problems to be solved in order to achieve mastery of the competencies established in a training unit;
3. Select the most appropriate ways to promote the learning of conceptual, procedural and attitudinal content in an integrated manner;
4. Use a varied selection of teaching strategies [21].

2.2 Innovation Description

In terms of the TEC21 Educational Model, an activity was designed that addresses the need for changes in training spaces to promote a high capacity for skill development and application of knowledge, which integrates elements of an active process of collaboration and life experience under the guiding axis of knowledge mastery-skill development, as well as the curricular definition that leads the student to complete their comprehensive training process based on transversal (TC) and disciplinary (DC) competencies. For the planning of the exercise, focused on the student and the level of competency development, a base collaboration group responsible for the deployment, monitoring and evaluation was integrated, made up of teachers linked to the course of training units or UF (spanish acronym for Unidades de Formación), effectiveness staff and student mentoring [22].
The activity aimed at engineering programs (2019 plans) of the Tecnológico de Monterrey, established in the first and second periods, scheduled in the second academic semester February-June of 2023,

allowing the inclusion of students, 28 and 30, enrolled in the Bioengineering and Chemical Processes, Innovation and Transformation, and Applied Sciences avenues.

Essential parts
Competencies
- Identification of the level of scope and linked UF, **Figure 2.**

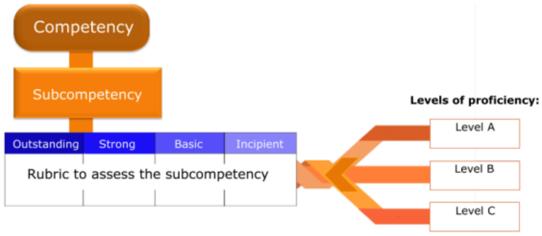

Fig. 2. Context of achievement levels when competency is assessed in a UF

- Attitudinal and procedural knowledge that precedes, student's own conditions, progress-moment in the study plan.

Didactic strategy and auxiliary techniques:
- Active learning, linked to reality and Collaborative Learning (CL) to maximize individual and group learning; both focused on seeking to develop skills in challenge resolution (CBL), openness to dialogue, interaction and reflection.
- Training in key elements of the base academic group, MTec21 Didactics. - Integration of collaborative work teams.

Significant spaces for collaboration:
- Classroom and laboratories for individual activities that are integrated into teamwork, with elements of a work context (problems, definition of common objectives, leadership, self-management to reach completion and delivery).

Procedural and attitudinal content
- Modularization of theoretical-practical content.
- Definition of stages for solving the problem
- Guiding conditions to know the criteria for participation and development of the activity.

Evaluation:
- Evaluation committee made up of the group of teachers.
- Observation rubric, measurement of the competencies by individually evaluating evidence based on key actions, **Table 1.**

Table 1. Example of bases for the structuration of an observation rubric

Competencies		Quality criteria
Correctly solves problems of reality, based on precisely delimiting the problem and the intervening variables, selecting and strategically applying the appropriate methods and techniques to analyze information, and correctly interpreting. Integrate the results to propose the solution.	Solves the questions of reality	correctly
	Defines the problem and the variables	with precision
	Selects and apply methods and techniques	relevant
	Interpret the results	in integrated way

The evaluation considers general observation rubrics and survey. The general observation rubrics measures the progress on the challenge, content, self- and peer-assessment (**Table 2**) while survey supports the final stage of evaluation and reflection. As indicated in **Table 2**, the level of achievement is defined in four terms: Outstanding 100 (greater than or equal to 95), Solid 88 (81-94), Basic 75 (70-80) and Incipient 55 (Less than or equal to 69).

Table 2. Observation rubric example

Nivel	Outsanding	Solid	Basic	Incipient
	100	88	75	55
Generic Descriptor	Shows *optimal performance* , corresponding in its totality (or almost) to the demands of the sub-competencies, aligned with the correct defined for the evidence.	Shows *appropriate performance* , corresponding mainly to the demands of the sub-competencies, aligned with the correct defined for the evidence.	Shows *acceptable performance* and manages to meet the minimum demands of the sub-competencies, aligned with the context defined for the evidence.	Shows poor *performance* and therefore fails to meet the demands of the sub-competencies, aligned with the correct defined for the evidence.

As technological tools, Canvas platform, Excel and Mentímeter were used.

2.3 Implementation of the Innovation

The academic group in charge, previously trained, participated in a differentiated way, assuming various roles: action research, designers, facilitators, mentors, tutors, and evaluators. The mentor and director facilitated interviews and information that allowed the evaluation of scenarios of action by the students, for example risk factors. It should be noted that, due to an agreement on the handling of confidential information, some data and real names of people are omitted in this report.
The competencies to be developed were identified, which are conducive to the graduate profile of the engineering careers (Chemistry, Biotechnology, Sustainable Development, Industrial Engineering, Data Science Engineering, Mechanics Engineering and Agrochemistry).
The participating UFs were: F1010B-Application of thermodynamics in process engineering (24 students) and F1011B-Analysis of electrical systems in process engineering (30 students). By delimiting the work's extension, an example of identified TCs is shown in **Table 3.**

Table 3. Example of TCs in the UF impacting the graduate profile

Competencies in UF	Level of achievement	Graduate profil competencies
Solves problems and questions about reality, based on valid and reliable methodologies.	A	Solve problems
Evaluates the solidity of one's own and others' reasoning, based on the identification of fallacies and contradictions, which allows them to form their own judgment regarding a situation and problem.	A	Critical thinking
Evaluates various information technologies, with openness in the search and implementation of relevant alternatives in the transformation of professional practice	A	Management of information technologies

To justify the expected levels of achievement in the focus groups, two actions were carried out:

- The preparation in knowledge and skills of previous UFs (F1002B Period 1: Process modeling and F1003B Period 2: Conservation laws in process engineering) was recognized (**Tables 4** and **5),** beginning on the exploration stage.

Table 4. Competencies and achievement level at UF, first and second semester

Stage: Exploration. Disciplinary Competencies			
UF/Disciplinary Competencies	**Substantiates**	**Solve Problems**	**Period**
F1002B	Explains (A)	Make decisions (A)	1/2nd
F1003B	Demonstrate (A)	Implement actions (A)	1/3d
F1010B	Explains (B)	Evaluate components (A)	2/1st
F1011B		Evaluate components (A)	1/2nd
		Generate proposals (A)	

Table 5. Competencies and achievement level at UF, first and second semester

Stage: Exploration. Transversal Competencies				
UF/ Sub Competencies	Reasoning	Comunication	Digital Transformation	Semester/ Period
F1002B	Critical Thinking Solves question problems (A)	Written language (A)		1/2nd
F1003B	Scientific Thinking Solves question problems (A)	Written language (A)		1/3d
F1010B			Evaluate and look for alternatives (A)	2/1st
F1011B	Scientific Thinking Solves question problems (A) Scientific Thinking Evaluate your own reasoning (A)			2/2nd

- A general overview of risk and protection factors was provided for review, the measurement of which is derived, in terms of High, Normal and Low levels, from the application of a survey upon admission, for example:
  - *Resilience (R). Adaptive ability to get ahead or recover from a stressful situation.*
  - *Comprehensive well-being (CWB). Social and psychological prosperity, taking an interest in one's activities, feelings and emotions.*
  - *Psychological flexibility (PF). Positive evaluation of emotions, coping with feelings and emotions.*
  - *Goal orientation (GO). Setting goals and having the motivation to achieve them.*
  - *Support networks (SN). Perceiving that they have the support of peers, family, tutors and mentors*.

The percentage of students in the interest groups that reflected a Low level in the different protection factors were *R*: 29 %; *CWB*: 14 %; *PF*: 7 %; *GO*: 7 %. Only *SN* showed a response at High and Normal levels.

Then, the workspaces and theoretical-practical content were established by the academic team defining:

- Classrooms for interaction and laboratories for experimentation.
- Modularization and programming oof dosed knowledge during the process of solving the challenge (corresponding to Mathematics, Computing and Physics in a greater concentration).
- Multidisciplinary teams of 3-4 members.
- Active process that integrated the elements of collaboration to solve a challenge, and programming of the theoretical-experimental progress, of the time period corresponding to 5 weeks (**Figure 3**).

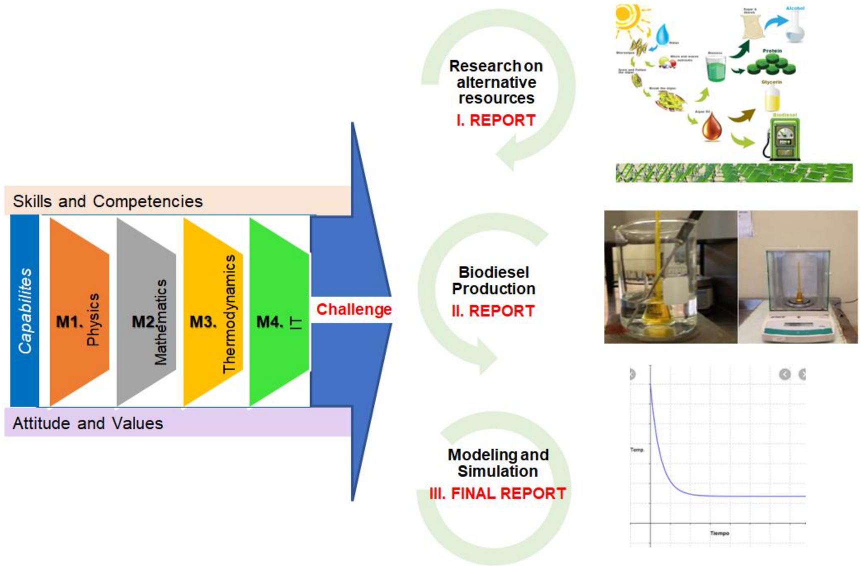

Fig. 3. Example of modularization of content in a UF

Example of challenge: *Modeling and Simulation of the charge and discharge processes of an RC circuit powered with an alternating voltage source*

Objective: Design and build an electrochemical cell system using natural substrates that supplies voltage to an RC circuit and simulate its charge and discharge process in Matlab.

The performance measurement corresponding to a level of competency achievement was carried out based on the observation guides and is exemplified in **Table 6**, with an individual measurement.

Table 6. Example of individual result obtained from the observation rubric

Student A	Outstanding	Strong	Basic	Incipient	Did not provide evidence
	4	3	2	1	0
SEG0502 Solves problems and questions of reality, based on valid and reliable methodologies					
SEG0502	Correctly solve the questions of reality, starting from precisely defining the problem and the intervening variables, selecting and strategically applying the relevant methods and techniques for information analysis, as well as correctly interpreting the results to propose the solution.	Correctly solve the questions of reality, starting by clearly defining the problem and the intervening variables, by strategically selecting and applying the relevant methods and techniques for information analysis, as well as by correctly interpreting the results to propose the solution.	Partially solves the questions of reality, by defining the problem and/or the intervening variables with imprecisions, by selecting and applying the relevant methods and techniques for information analysis inconsistently, as well as by interpreting the results in an acceptable way to propose the solution.	Incorrectly solves the questions of reality, by vaguely delineating the problem and/or the intervening variables, by selecting and applying the relevant methods and techniques with errors for the analysis of information, or by misinterpreting the results to propose the solution.	Did not provide evidence

In parallel and through the availability of information on the institutional platform, a comparison was generated between the interest group and the total population, regarding the level of achievement of the competencies (**Figure 4**).

Fig 4. Example of a comparison of achievement levels, interest group – total population

3. Results and Discussion

Educational models require a component of systematic analysis on variables that intervene in the process to contextualize the moment and conditions in which the student finds himself; giving way to the design of strategies, methodologies and guidelines that favor the development of competencies; expressed with continuous adaptation.

Collegial collaboration, Academia, Mentor, and Institutional Effectiveness were essential to guide the work in a clear and strengthened context within the educational process that required the mastery of knowledge and development of competencies.

Through the Mentimeter platform managed by the collegiate group, the application of perception and training monitoring surveys was made possible at the end of the period, they recognized in collaborative work the following skills: analysis-synthesis, decision-making, communication, and time management (**Figure 5).**

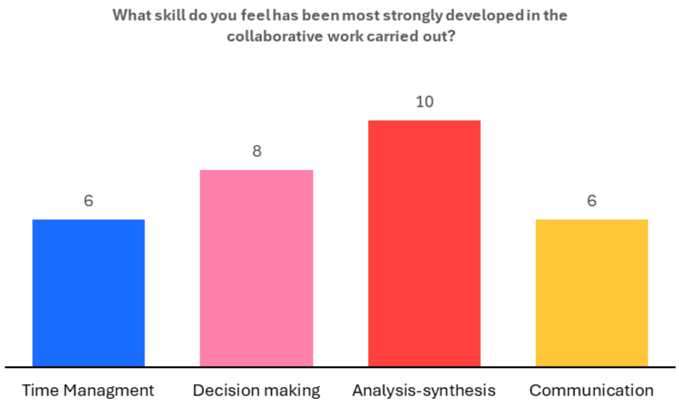

Fig. 5. Example of perception and trainned skills in collaborative work, interest group

- To carry out collaboration: co-responsibility, active listening, tolerance.
- For professional development: problem solving, knowledge of processes, evaluation of properties
- Skills learned from someone on the team that helped improve the learning process: understanding, optimism, resilience and not giving up, tolerance, problem solving, analysis and description, analytical thinking, commitment, effort, perseverance, methodology, dedication, preparation time.
- When facing the resolution of a real problem: Knowledge of methodologies for problem solving, life experience, learning in a real context, development of skills.

Results obtained from the institutional survey confirmed that the strategy is a favorable condition for achieving objectives:

Student A: … "*it makes me more perseverant, especially learning to study, to know the origin of things and indirectly forcing myself to grow as a person*".

Student B: … "*feeling limited in concepts and computing generated a lot of frustration, but when I began to analyze the problems and look for ways to justify them, I accepted the challenge to continue.*

The identification of precedents and the analysis of the competencies to be developed in relation to their level of achievement and impact on the competencies defined in a graduate profile, was essential to contextualize the moment and the conditions that the student presented during the process of developing the competencies.

The incorporation of differentiating elements of auxiliary techniques such as active and collaborative learning, to a base scenario of challenge resolution, fostered significant learning environments and the development of skills; In summary, the student:

- Faced with the scenario of searching for and analyzing alternative solutions to a proposed challenge in multidisciplinary collaboration teams, being sensitive to the need to know to collaborate, showing more open behavior, flexibility and tolerance in interaction and more active participation.
- Distinguished in practice the different roles of the group members: project integrator, guide for the fulfillment of objectives, results verifier.
- Skills for interaction were strengthened such as listening and effective communication.
- In the solution process, he analyzed and evaluated components, reflected on conditions, made contributions from his area of knowledge, formulated judgments on the proposal and made decisions.
- It was important for the student to work in a collaborative and orderly manner, allowing him to learn from others, learn and apply methodologies, and enhance the development of new skills in the context of co-responsibility and organization.

The integrated measurement by the evaluation of individual evidence confirmed the level of achievement of the competencies. Although, due to the interest of the study, emphasis was placed on the DCs of the UF, the analysis of the skills that are recognized to be developed or strengthened allowed us to conclude about the impact on other graduation competencies: leadership, intellectual curiosity and passion for learning, collaborative work.

Similar results were found in similar studies and contexts. In a case study in the linguistics department at Necmettin Erbakan University in 2018-2019, 28 students in a Project-Based Learning (PBL) declared in the interviews that the activity dealing with a social problem developed in them skills such as active learning, creativity, motivation and critical thinking; these considered lifelong learning skills [24]. In another work at the Portucalense University in Portugal with 18 students of the first year of the Social Education bachelor´s program, the students recognized critical thinking, capacity for initiative, creativity and project management (research skills, decision making and organization) like lifelong learning skills gained when they had a PBL experience using generative artificial intelligence (IA) tools for supporting the project development [24]. Both references evidence the role of CBL at the university level for enhancing lifelong learning skills.

3. Conclusions

The challenging world requires professionals with constant abilities for lifelong learning. These skills can be shaped in undergraduates in higher education through real contextualized experiences with CBL. Tec21 Model, with their elements, contributes to the development of lifelong learning skills found as transversal or disciplinary competencies in its engineering programs. Hence, in this intervention, a formed academic group with multiple roles designed real scenarios where engineering students of the first semester solve problems by applying TCs and DCs in a collaborative environment with CBL and giving them theoretical and practical content.

In the applied surveys, the undergraduates manifested that during the collaborative work, analysis-synthesis was the skill better developed, followed by decision making in second place, and time management and communication as both skills in the third place.

The results show the impact of the experience when incorporating differentiating elements in the teaching-learning process for the development of competencies in response to a need for change. Among some other findings, several important ideas were found and reaffirmed. Personalizing learning maximizes life experiences and reflection, thereby emphasizing the flexibility of the scenarios. A collaborative environment raises the capacities to do, based on continuous learning and social interaction, governed by cognitive flexibility, leading to more open, organized, and systemic behavior.

As final reflexion, it is recommended that the experience be projected in equivalent scenarios, suggesting to continue with the study to systematize the relationship between risk factors and development of competencies throughout the curricular program and obtain more conclusive results.

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