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Study of the Impact on the Development of Competencies: Collaborative Learning and Problem Solving by Engineering Students in a Multidisciplinary Context of Total Immersion

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Abstract: One of the most observed trends in Higher Education is the development of competencies to equip undergraduate engineering students for solving problems that they will confront in real-world situations. One way to develop these competencies is by exposing students to scenarios where they have opportunities to apply the information they have learned beyond an academic level and thereby acquire new, relevant knowledge. The purpose of this paradigm shift in education is to decrease the existing breach between learning in the classroom and learning in work-and-social environments in such a way that learning thus becomes a natural and continuous activity rather than one programmed and limited to university classrooms and labs. This present study shows how multidisciplinary teams of engineering students were called upon to solve a challenge for a week in the context of total immersion in a real-world environment. The study shows how students develop collaborative work skills while generating and applying new knowledge during the process of proposing a solution to the challenge. The importance of collaborative work skills among the team members was observed as a predictor of success in solving this challenge.

Keywords: Educational innovation, Competency development, Collaborative learning, Higher education

Introduction

"I'm not interested in hiring engineers or people with master's degrees or Ph.D. s; I hire people who know how to solve problems and communicate. My strategy to hire is the same as to hire a pianist; a black curtain, the pianist plays on the other side, we listen to him, and then we decide." Thus, began the talk of an entrepreneur at the National Meeting of Teachers (July 2017) of a private educational institution. This talk helped to create a framework of reference to many of the actions that teachers had incorporated into their practice. This event was essential to identify the elements that were needed to be incorporated so that the students of the Institution would generate, from the first semesters, a background of knowledge, skills, and values that would be useful to them when they had to deal with the diverse situations of their working and social lives.

The candidates for graduating from this Institution complete an opinion poll in their final semester of study. One of the most recurrent comments within this survey is about the big difference between the knowledge taught in the classroom and that required for professional life (Villarroel & Bruna, 2014). A second comment relates to the collaborative work that they develop at the university and that it differs significantly from what companies need from a professional; this has also been observed by different authors ((Aguilar Pérez, Cedillo Cuadros, & Valenzuela González, 2015; Guenaga, Eguíluz, Jerez, & Torientes, 2015; Marín, 2017; Morita-Alexander, García-Ramírez, & Escudero-Nahón, 2016; Rivero, Martín, & Gil, 2015; Yepes, Martí, & Garcia-Segura, 2016). These differences between academia and the work world often create obstacles to the recruitment of new

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

graduates in key positions of organizations. The Institution, seeking to identify and understand better the skills that the country, society, and companies require from graduates, consulted with employers, graduates, and civil society; the results caused re-thinking about the educational model of the Institution, in such a way that the model "…aligns the key elements of the vision, organization, and culture of the institution" (Guenaga et al., 2015; López López, Guerrero, José, & Pérez-García, 2018). This re-thinking was denominated as the Tec21 Educative Model.

In an underlying way, The Tec21 model bases an important part of its strategy on the methodology of solving challenges, which are incorporated into different subjects and, specifically, in a format of total immersion during a one-week period that we will call "*IT*.". For the Tec21 model, a challenge is a lived experience designed to expose the student to a challenging situation in the work environment to achieve specific learning objectives. These challenges are expected to contribute to the development of disciplinary and transversal competencies in students as they apply their learning, skills, attitudes, and values individually and collaboratively (ITESM, 2018).

Tec21 and the *IT* seek to achieve the development of both generic (transversal) and specific (disciplinary) competencies. For the Tec21 model, competencies are defined as the conscious integration of knowledge, skills, attitudes, and values that enable students to face both structured and uncertain situations. Competencies include both the knowledge and the procedures of the discipline, as well as the attitudes and values that are necessary for trained professionals who are committed to society.

In the Tec21 Educational Model, there are two categories of competencies; namely, the disciplinary and the transversal. Disciplinary competencies refer to all the knowledge, skills, attitudes, and values that are considered necessary for professional exercise. The development of disciplinary competencies involves a gradual construction starting from the fundamental skills until reaching the terminal competencies of the discipline. On the other hand, the transversal competencies are developed throughout the process of training in any discipline; they are useful for the life of the graduate and have a direct impact on the quality of the exercise of the profession (ITESM, 2018)

Both categories are already defined by this Institution. The transversal competencies are disseminated throughout the curricula of the entire Institution, and the disciplinary ones are established by each School (Engineering; Humanities and Education; Medicine, Architecture, Art and Design) (Maura & Tirados, 2008). According to Bezanilla et al., (Bezanilla et al., 2014; Núñez-Lopez, Avila-Palet, & Olivares-Olivares, 2017; Villarroel & Bruna, 2014) the competencies have the following characteristics: they must be based on actions relevant to meet the challenge that they have to solve; must be learned in a context of total immersion; and also be verifiable, and they must involve a broad range of procedures, attitudes, and skills. The week of *IT* allows teachers to develop, in one activity, two generic and two specific competencies, that fully comply with all the elements set out in the previous paragraph.

Description of the Challenge.

Focused on helping to narrow the gap between theoretical knowledge and the solution of real problems, as well as developing collaborative teamwork skills more relevant to the training of students to be engineers, we developed a challenge that consisted of designing and constructing a handcrafted bread oven with the capacity to cook at least 3 pieces per lot. The bread would have to meet the minimum characteristics of well-cooked bread. Among the essential requirements for the oven, the cost should be less than $75, efficiently conserve energy, and maintain low levels of pollution. The challenge was called "Pan Cracio." In this challenge, we sought to develop the generic competencies of problem-solving (Csp) and collaborative work (Ctc) and the disciplinary competence of energy conservation. The schedule of the week's activities for the challenge is shown in Figure 1.

Pan Cracio was included in the catalog of challenges that the Institute offered to its students at the national level. In this catalog, the objectives of the challenges, their agendas, forms of qualifications (including rubrics), and the disciplinary and transversal competencies to be developed were described in the offering, so that the students could make informed selections.

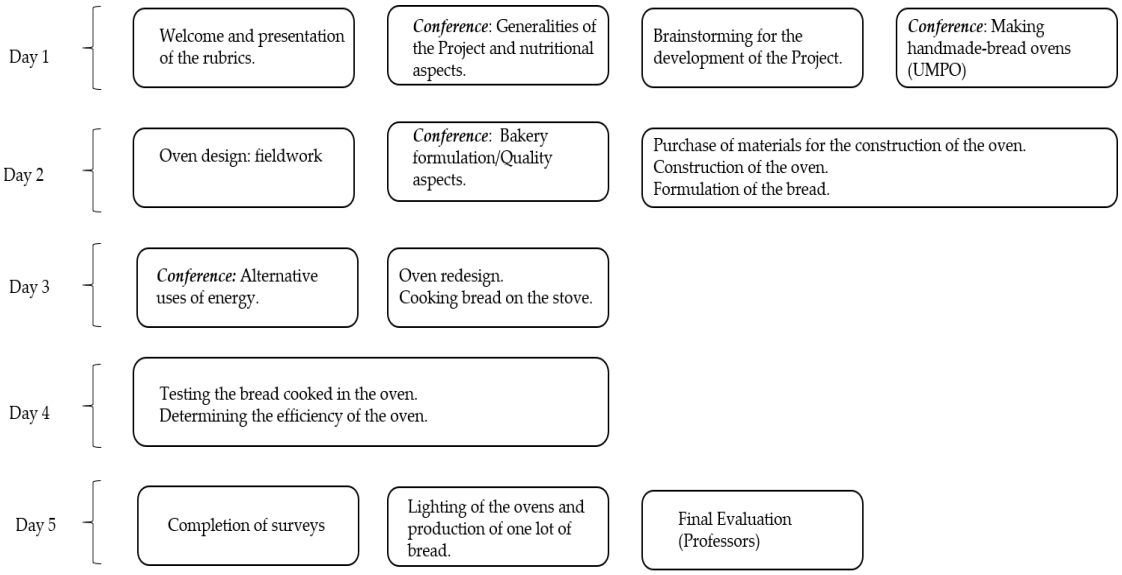

Figure 1. General activities agenda of Pan Cracio

Technical Considerations for the Application of the Challenge

For the formation of the teams, it was determined that each would have members from different academic programs, similar to working environments and that the proportion of students in each curriculum and semester would be as homogeneous as possible. This situation caused bewilderment among students on the first day of activities because they had hoped to work with classmates and friends. The decision about the composition of the teams was made so that communication would flow in as many channels as possible (Carrasco, Fernández, & Perera, 2018).

Although students knew in advance the formats by which they would be assessed for the challenge, they were shown again at the beginning of the activity (Carrizosa & Ballestero, 2012). During the introduction, the following aspects were also emphasized to the students: teamwork, self-assessment, and freedom of the schedules. In this way, they were made responsible for successfully finishing the project (Barraycoa-Martínez & Lasaga-Millet, 2010; Benito, Villaverde, Hortig-ela-Alcalá, & Abella-García, 2016).

Although the group of students had some clarity of what was expected of them in the project, some questions were left unresolved at first, such as, "What is an efficient oven?"; "How is an oven built?"; "What temperature is required inside the oven to cook?" and "What is well-cooked bread?" Leaving these questions unresolved at the beginning was part of the strategy of problem-based learning (Guerra, Mesa, & González, 2017).

During the construction of the oven, the teachers remained mostly as observers of the process; however, they could intervene in extreme cases (Estrella, Pareja, & Tudela, 2015). Their function was to foster opportunities for growth and improvement for the students, generating a conducive environment for dialogue and cooperation (Fernández-Jiménez, Polo, & Fernández Cabezas, 2017; Gallego & Rodríguez, 2017; Morales, Pineda, & Saucedo, 2017). It is important to consider that the challenge-solving strategy is unsuccessful if the students do not fail in some of their approaches (Carrasco et al., 2018).

As part of the challenge, there were four mandatory conferences to attend. The first conference provided general information on the problem to be solved and on the nutritional aspects of bread. The second guided students about cooking handmade bread in ovens, its characteristics, and quality parameters. The conference was given by the association, One Hand for Oaxaca (UMPO). This conference also discussed the social aspects related to Oaxaqueño bakers. The third conference was devoted to the process of formulating the bread and its quality parameters, while the fourth conference was about the alternative use of energy.

From the first day, the students brainstormed, made decisions, and began the construction of the oven, even though they had not received complete information for the process (Carrasco et al., 2018(Saldaña, Contreras, Navarro, & Velásquez, 2017), (Saldaña, Contreras, Navarro, & Velasquez, 2017). This work continued during the week, and the students integrated the knowledge they acquired either on their own or in the conferences through interactions with the invited specialists.

While the present project was born with the idea of strengthening generic problem-solving and collaborative work skills, it was hoped that by knowing the social situation of the Oaxaca bread producers after the recent earthquake in the region, the students would be sensitized to a real, devastating, and current situation, which required intervention and the planning of solutions (Carrasco et al., 2018; Estrella et al., 2015; Lopez, 2015). In this way, the students might develop sensitivity to the social problems that are part of our country.

Method

Objectives

To **e**valuate the development of transversal skills**,** particularly collaborative teamwork and problem-solving, in a group of students from various academic engineering programs from different regions of the country in a multidisciplinary environment in an experience of total immersion.

Population and Sample

The study population corresponded to the students enrolled in the Professional curricula of the August-December 2018 semester, in which were represented the 11 engineering programs of several campuses of the university system located in different states of the republic. The invitation to participate in the Pan Cracio activity was sent; and the subsequent enrollment included 46 students from 9 academic programs: Agricultural Engineering (IA), Biotechnology Engineering (IBT), Civil Engineering (IC), Food Industries Engineering (IIA), Industrial and Systems Engineering (IIS), Mechanical Engineering Administrator (IMA), Electrical Mechanical Engineering (IME), Engineering in Mechatronics (IMT), and Bachelor of Industrial Design (LDI). The students were in semesters 2 to 5 and came from 8 cities or states; namely, CDMX: Mexico City; CHS: Chiapas; EMX: State of Mexico; MTY: Monterrey; PBA: Puebla; QRO: Querétaro; SFE: Santa Fe; and TOL: Toluca. The enrolled students were grouped into seven teams, which were formed accounting for various factors such as their academic programs, semester and campus of origin to assure the highest homogeneity possible among the teams.

Instruments

The study used two types of evaluation tools: the set developed by the professors who designed the activity and the instrument employed by the Institution for assessments. The activities set was comprised of 6 rubrics and two surveys (one entry [EE] and one exit survey (ES]) to assess the development of the competencies selected for the activity. The Institutional Survey (EI) was given to participants of all *IT* week activities throughout the university system. Its purpose was to give feedback to the Institute on general aspects of the quality of the activity and the level of satisfaction perceived by the students.

Some of the rubrics developed by the professor-designers had previously been used in the evaluations of groups of students in some engineering programs in curricular subjects such as Inorganic Chemistry and Organic Chemistry, among others. Also, another set of rubrics was developed specifically for the activity. The list of rubrics used, the information about their design, the types of competencies evaluated, the person responsible for their completion, and their weighting in the final grade is shown in Table 1. The rubric formats are included in the Appendices.

The surveys were intended to evaluate the students' expectations for activity (EE) and their fulfillment at the end (ES), as well as to provide a space in which their opinions regarding their participation in Pan Cracio could be freely expressed. The formats of these surveys are shown in the Appendices.

Table 1. Rubrics for the development of competencies

Rubric Name	Design Type*	Type of Design Evaluated&	Responsible for Completion#	Weighting in the Final Grade
Bread (P)	A	D	P	30%
Oven (H)	A	D	P	25%
Contamination (C)	A	D	P	15%
Energy (E)	A	D	P	15%
Self-assessment (AE)	P	T	A	5%
Co-evaluation (CE)	P	T	C	5%
Collaborative Work (TC)	A	T	P	5%

Design Type*: A: Designed for the activity; P: Designed previously.
Type of competency evaluated&: T: transversal, D: Disciplinary
Responsible for completion#: P: Professor group, A: Student; C: Student team members

Description of the Rubrics

The P rubric aims to evaluate the quality of bread cooked in the oven. This rubric includes measuring its sensory properties (such as smell, color, and texture), as well as the percent of mass growth, its nutritional value, and its cost. The H rubric evaluates the construction of the furnace, considering the parameters of functionality, safety, and energy efficiency. Rubric C assesses the emanation of polluting gases during furnace operation, the review of applicable regulations, and the implementation of devices in the furnace to reduce contamination. The E rubric evaluates the alternative uses of the energy generated by the oven that is not used in the cooking of bread and considers parameters like cost and the importance of alternative uses. The AE and CE rubrics aim to measure the level and quality of student participation in the development of the project, their appreciation, and that of their teammates.

Table 2. Questions that compose the Institutional Survey EI

Question Number	Key	Question	Scale
1	SICLA	The professor established what he expected of me during the development of the activity.	0-10
2	SIEVA	The professor clearly explained to me how the activity would be evaluated.	0-10
3	SIGUI	The professor provided me with guidance and advice during the learning process of the It activity.	0-10
4	SICON	Everything you did in the It activity allowed you to learn new knowledge or apply what you already knew.	0-10
5	SIMET	I had access to clear and accurate explanations and learning techniques or technological tools that facilitated the activity.	0-10
6	SIREF	In the activity in which I participated, there were spaces where I could reflect upon my acquired knowledge.	0-10
7	SIORG	Through the activity, I realized the contribution of value that I can make to the community, the organization, or society in general.	0-10
8	SIRET	The activity offered a different challenge than my classes.	0-10
9	SIACT	I consider that my attitude played a very important role in the outcome of the activity and learning that I acquired.	0-10
10	SIAPR	I think the learning acquired can be applied in other situations.	0-10
11	SCOM	I developed the competencies that the teacher said we would acquire through the activity.	0% -100%
13	SISAT	How satisfied do you feel about participating in this *IT* activity?	0-5
17	SIREC	I would recommend this *IT* activity to my classmates.	0-5

For the study, it was established that the weighted average (Table 1) of the grades obtained under headings P, H, C, and E (HO) would be the indicator for the development of the Problem-Solving (Csp) competency; on the other hand, the grades obtained in TC, AE and CE were used as indicators for the development of the Collaborative Work competency (Ctc). The rating report also includes the parameters, End of Collaborative Work (FC), which corresponds to the weighted sum (Table 1) of the grades obtained in AE, CE and TC; and the Final Grade (FF) parameter, which corresponds to the final grade reported for the Pan Cracio activity. EI, the Institutional survey was developed by a group of professors of the Institute based on the observations made in the three previous offerings of the *IT* week. The institutional survey consists of 13 questions evaluated with three different scales (Table 2). For the study, questions 1,3,4,8,9,10 and11 were selected as indicators of the development of the competencies under study.

Procedure for Data Collection and Analysis

Data Collection

Data collection was carried out through the application of different rubrics and the surveys, which were administered as described in Table 3. The results of the rubrics were expressed as numeric values on a scale from 0 to 100.

Table 3. Delivery times of the rubrics and their formats.

	Stages of the activity		
	Before beginning	Beginning (Day 1)	End (Day 5)
Format	Delivery to Professors	Delivery to Students	Completion of Rubrics
Printed materials	Bread		Bread: professors
	Oven		Oven: professors
	Contamination		Contamination: professors
	Energy		Energy: Professors
	Self-assessment		Self-assessment: students
	Co-evaluation		Coevaluation: team members
	Entrance Interview		Entrance interview: student
	Exit Interview		Exit interview: student
Electronic materials			Institutional survey: students

Data Analysis

All grades obtained from the application of the rubrics were analyzed using Statistica version 13.3 software (Tibco Software, Inc.). An ANOVA analysis was performed for the results obtained in the rubrics by CPS (campus), EQ (team), CARR (curriculum), and SEM (semester) to identify significant differences ($p<0.05$). Additionally, a Fisher's (LSD) test was performed for each competency-assessment parameter to examine the population averages, to group the samples according to the factor evaluated. A correlation analysis was also performed to know the degree or intensity of association among the evaluated variables and also to know their relevance and the meaning of such an association (positive or negative).

Table 4: Minimum, maximum and average values for the assessments

	Minimum	Maximum	Average	SD%	Scale
TC	3.25	5.00	4.86	0.37	0-5
AE	4.58	5.00	4.99	0.06	0-5
CE	2.94	5.00	4.91	0.31	0-5
FC	11.20	15.00	14.78	0.63	0-15
HO	62.70	84.50	74.60	6.54	0-100
FF	73.90	99.50	89.43	6.64	0-100

TC: Collaborative Work, AE: Self-evaluation, CE: Co-evaluation, FC: Collaborative Final, HO: Oven, FF: Final Grade.
SD%: Standard Deviation.

Results and Discussion

Rubric Results

The minimum, maximum, and average values, as well as the standard deviations (DS) of the grades obtained from the application of the rubrics, are shown in Table 4.

Variance Analysis (ANOVA)

a) ANOVA for the teamwork competency (collaborative work). The results obtained by ANOVA for Ctc are shown in Tables 5-8. The analysis indicates that there is no significant difference ($p<0.05$), for TC, AE, CE, and FC when the data were analyzed by EQ, CPS, CARR, and SEM, so it can be said that there is no significant difference in the development of Ctc for these parameters. On the other hand, Fisher's test results showed differences for AE when analyzed by CPS, CARR, and SEM, whereas there are no differences for the rest of the evaluation parameters. Fisher's test grouped the data into three different categories for CPS, CARR, and SEM.

Table 5. ANOVA and Fisher's test results by team number

		EQ [%]						
Parameter[&]	p Value[#]	1	2	3	4	5	6	7
TC	0.493	5.00a	5.00a	4.972a	4.55a	4.73a	4.89a	5.00a
AE	0.263	5.00a	5.00a	5.00a	5.00a	4.94a	5.00a	5.00a
CE	0.558	5.00a	5.00a	5.00a	4.9a	4.69a	4.87a	5.00a
FC	0.457	15.00a	15.00a	14.97a	14.46a	14.36a	14.75a	15.00a

[&]TC: Collaborative Work, AE: Self-evaluation, CE: Co-evaluation, FC: Collaborative Final.
Significant to $p<0.05$
EQ[%]: Team Number (1-7)

Table 6. ANOVA and Fisher's test results by originating campus

		CPS (campus) [%]							
Parameter[%]	p-Value[#]	CDM	CHS	EMX	MTY	PBA	QRO	SFE	TOL
TC	0.8599	5.00a	5.00a	5.00a	4.55a	5.00a	4.89a	5.00a	4.93a
AE	0.4313	5.00a	5.00ab	5.00ab	4.90b	5.00ab	5.00a	5.00a	5.00a
CE	0.9061	5.00a	5.00a	5.00a	4.90a	5.00a	4.94a	5.00a	4.92a
FC	0.9641	15.00a	15.00a	15.00a	14.39a	15.00a	14.79a	15.00a	14.85a

%TC: Collaborative Work, AE: Self-assessment, CE: Co-evaluation, FC: Collaborative Final.
Significant to $p<0.05$
CPS%: Originating campus of the student: CDM: Mexico City, CHS: Chiapas, EMX: State of México, MTY: Monterrey, PBA: Puebla, QRO: Querétaro, SFE: Santa Fe, TOL: Toluca.

Table 7. ANOVA and Fisher's test results by student's curriculum

		CPS (campus) [%]								
Parameter%	p Value#	IA	IBT	IC	IIA	IIS	IMA	IME	IMT	LDI
TC	0.8275	4.45a	5.00a	4.79a	4.97a	4.93a	5.00a	5.00a	4.99a	5.00a
AE	0.5937	5.00ab	5.00a	5.00a	5.00ab	4.93b	5.00ab	5.00ab	5.00ab	5.00ab
CE	0.9704	4.77a	5.00a	4.86a	4.96a	4.92a	5.00a	5.00a	4.97a	5.00a
FC	0.9090	14.22a	15.00a	14.65a	14.93a	14.77a	15.00a	15.00a	14.97a	15.00a

%TC: Collaborative Work, AE: Self-assessment, CE: Co-evaluation, FC: Collaborative Final.
Significant to $p<0.05$
CARR%: Originating curriculum of the student: IA: Agricultural Engineering, IBT: Biotechnology Engineering, IC: Civil Engineering; IIA: Food Industries Engineering, IIS: Industrial and Systems Engineering, IMA: Mechanical Engineering Administrator, IME: Mechanical-electrical engineering, IMT: Mechatronic Engineering, LDI: Licensed in Industrial Engineering

Table 8. ANOVA and Fisher's test results by semester

		SEM[%]			
Parameter%	p Value#	2	3	4	5
TC	0.3877	4.97a	4.90a	4.77a	4.70a
AE	0.0805	5.00a	5.00a	4.93b	5.00a
CE	0.1401	4.96a	4.98a	4.92a	4.65a
FC	0.2098	14.92a	14.87a	14.63a	14.34a

%TC: Collaborative Work, AE: Self-assessment, CE: Co-evaluation, FC: Collaborative Final.
Significant to $p<0.05$
SEM[%]: Semester that the student is coursing (2 a 5)

b) ANOVA for the Problem-Solving Competency. The data indicated that there is no significant difference in the development of the Csp among students from different campuses, careers or semesters; but there is a different level of competency development among the different teams: HO (oven) showed a highly significant difference (p.0.00001) when analyzing the data by team, with team 6 having the highest grade (84.5%) and team 5 the lowest (62.7%).

Correlation Analysis

Table 9 shows the correlation between the results of the evaluations. This table shows a positive correlation between CE and TC; which would indicate a correspondence between the observations made by the students and those made by the teacher, and also, it would be an indication of the validity of the design and the implementation of the measuring instruments for these parameters.
Table 9 also shows a positive correlation ($p<0.05$) between FC and TC; as well as FC and CE, indicating that the grades obtained in TC and CE had a better relationship with FC than the grade obtained in AE. This again marks the concordance of the TC and CE observations. There is also a negative correlation between FC and SEM, indicating that the higher the semester the students are coursing, the lower is the grade obtained in FC. This observation agrees, albeit less importantly, for TC, AE, and CE, but not so for HO, so that it can be inferred that in general, Ctc develops inversely with respect to the semester of the students and that there are indications of better development of Csp in students of higher semesters. It can also be said that the development of Ctc is better observed by TC and CE than by AE.

Table 9. Correlations among the evaluation parameters analyzed (surveys).

Variable#	EQ	CARR	SEM	FF	TC	AE	CE	HO	FC
CPS	0.097	0.390	0.101	0.053	0.095	0.018	0.079	0.058	0.096
EQ		0.085	0.127	0.157	0.086	0.068	0.132	0.190	0.121
CARR			0.112	0.148	0.249	0.075	0.156	0.169	0.214
SEM				0.006	0.255	0.144	0.270	0.020	0.295
FF					0.092	0.291	0.237	0.995	0.199
TC						0.033	0.733	0.004	0.938
AE							0.039	0.281	0.059
CE								0.151	0.914

Significant to $p<0.05$; CPS: Campus, EQ: Team, CARR: Curriculum, SEM: Semester, FF: Final Grade, TC: Collaborative Work, AE: Self=Assessment, CE: Co-evaluation, FC: Final Collaboration

Results of the Entry Survey

The results of the entry survey (EE) are shown in Table 10. The students' opinions were analyzed and quantified by each of the competencies under study. The survey questions tended to explore the students' level of awareness of the primary purpose of the activity at the beginning of the *IT*.

In Table 10, students can be seen to show an important degree of awareness by issuing 30 opinions about the goal of developing Csp and 34 opinions regarding the development of Ctc (question 5), by which one can say that the students more or less know the objective of the immersion activity before it began. It can also be seen that students had high expectations (45 opinions) regarding the development of Csp (question 2). The survey also solicited student opinions related to the enthusiasm or interest in the topic selected for the work during the *IT* week.

Table 10. Results of the entry survey (problem-solving and collaborative-work)

Question Number	Question	Number of Opinions	
		Csp%	Ctc%
1	What motivated you to enroll in Pan Cracio as a Project of *IT*?	25	17
2	What expectations do you have for *IT*?	45	11
3	What knowledge do you hope to gain from this project?	4	9
4	What do you believe is the most valuable knowledge that you can learn in this project?	11	14
5	What competencies do you hope to develop in this project?	30	34

%: Csp: Problem-solving: Ctc: Collaborative Work (Teamwork).

These results indicate that the decision to participate in the activity was influenced in part by the interest of developing the competencies selected for the challenge. This fact is important for the study from the point of view that greater interest is expected to result in greater learning.

Results of the Exit Survey

The exit survey results related to the competencies of problem-solving and collaborative work (teamwork) (ES) are shown in Table 11. The students' opinions were analyzed and quantified for each of the competencies under study. The survey questions tended to explore the students' awareness of developing these competencies by the end of *IT*.

Table 11. Exit Survey results

Question Number	Question	Number of Opinions	
		Csp%	Ctc%
1	Were your expectations of *IT* fulfilled?	0	8
2	What knowledge did you obtain from this project?	15	28
3	What do you consider was the most valuable learning from this project?	10	29
4	What competencies did you develop in this project?	18	77
5	What aspects or skills do you consider as the most important in the project?	*	12

%: Csp: Problem-solving, Ctc: Collaborative Work (Teamwork)
* Specific answers were not given.

The exit survey (ES) shows a significant increase in the number of Ctc-related (teamwork) student opinions compared to those issued in the entry survey (34 VS 77). This fact is an indicator of the relevance that the exercise of this competency had during the activity. *IT* is important to note that in the opinions expressed in the survey, the students emphasized the relevant aspects of the exercise of teamwork (Ctc), including tolerance, resilience, leadership, effective communication, time management, and empathy. This expression of opinions did not happen in the entry survey. Regarding problem-solving skills (Csp), the number of student opinions was notably lower than in the entry survey; however, comments were obtained related to the knowledge acquired, which were directly linked to this competency.

Results of the Institutional Survey

Of the 46 students enrolled in the activity, 37 responded to the survey, except for one of the parameters in which only 36 students responded. The parameters evaluated by the Institute, their keys, the average of the results obtained for each of them, and their standard deviations are shown in Table 12. In order to analyze the results obtained by the institutional survey (EI) with regard to the achievement of the competencies under study, questions numbers 1, 3, 4, 8, 9, 10 and 11 were considered. The results were as follows: that the students perceived clearly the competencies they wished to develop in the activity (1); they felt they had the guidance of teachers during the activity to develop these competencies (3); they acquired new skills (4); the learning during the activity was challenging (8); they understood that attitude towards work played a very important role in the outcome of the activity (9); that their acquired learning could be applied in other contexts (10); and that the skills developed favorably in 97% of students (11).

Table 12. Results of the institutional survey for the activity of the *IT* week.

Question Number	Question	Key	No. Op*	Average	SD&
1	The professor clearly established what he expected of me during the development of the activity.	SICLA	37	9.89	0.51
2	The professor clearly explained the method of evaluating the activity.	SIEVA	37	9.86	0.41
3	The teacher provided me with guidance and advice during the learning process of *IT* activity.	SIGUI	37	8.81	0.61
4	Everything you did in the *IT* activity allowed you to learn new knowledge or apply what you already knew.	SICON	37	9.86	0.47
5	I had access to clear and accurate explanations, including learning techniques or technological tools that facilitated the activity	SIMET	37	9.86	0.47
6	In the activity in which I participated, there were spaces for the reflection of acquired learning.	SIREF	37	9.32	1.79
7	Through the activity, I realized the contribution of value that I can make to the community, organization, or society in general.	SIORG	37	9.76	0.63
8	The activity presented a challenge different from my classes.	SIRET	37	9.68	1.3
9	I consider that my attitude played a very important role in the outcome of the activity and the learning that I acquired.	SIACT	37	9.59	1.68
10	I believe that the knowledge I acquired can be applied in other situations.	SIAPR	37	9.43	1.79
11	I achieved the competencies that the teacher said we would develop through the activity %	SCOM	37	97%	0.16
13	How satisfied do you feel about participating in the *IT* activity?	SISAT	37	4.3	1.16
17	I would recommend to my colleagues this activity at the next *IT* activity.	SIREC	36	4.25	1.14

*No. Op: Number of Opinions written by the students.
Media: Average number of the opinions of the students
&SD: Standard Deviation

Conclusion

The results of the study suggest that the Pan Cracio activity allows discriminating the work of the different teams of students with respect to problem-solving (Csp). It can be inferred that this was a challenging activity, which was one of the objectives of the course-offering. It was also found that there is no significant difference in the development of problem-solving skills among students from different campuses, semesters, or careers. This is important because the academic training of the students from the different campuses of the Institute is expected to be homogeneous. On the other hand, it can be inferred that the new knowledge needed to solve the challenge was accessible to students regardless of their semester or career, suggesting success in the homogeneous training of the teams and the type of knowledge required for the development of the activity. Curiously, it *was* found that the lowest grades in self-assessment (AE) were presented by the Monterrey students (MTY), the Industrial and Systems Engineering (IIS) students, and semester 4 students. The interpretation of these observations requires the application of assessment tools in different populations to validate their repeatability, which would support the idea that the students' ability to self-assess is not homogeneous considering such variables.

The study showed that there is a positive correlation between co-evaluation (EC) and teamwork (TC), which would indicate an important level of concordance of the perception of the quality of collaborative work from the point of view of both students and teachers. This is not the case with self-assessment (AE), suggesting the need to design activities in which students develop the ability to self-assess more objectively; while also designing and testing new assessment instruments that require more consideration of the responses, such as the public assignment of the grade and its reasoning to the task teams. Additionally, it would also be important to consider

narrowing the self-assessment grade to align self-assessment more with co-evaluation (EC) and collaborative work (TC), in order to avoid being employed by the student as a means of raising the final grade of the activity. The results of the study showed that students in the higher semesters had lower evaluations in collaborative work (Ctc) but scored higher grades in problem-solving skills (Csp). These observations would imply that students in the higher semesters, who have a higher level of knowledge, solved the challenge with less effort on their own, measured as a lower level of participation in the activity, as perceived by their peers and teachers.

From the above observations, it can be inferred that knowledge alone does not explain the success (measured as final grade FC) in the activity, but that success is best predicted by the interaction of the knowledge and the teamwork skills that the students possess. This is a reflection of what happens in work environments. The importance of design and student participation in this type of activity becomes, then, understandably important. In the case of the surveys, the entrance survey EE showed that the students decided to enroll in the activity because of their interest in the development of the problem-solving and teamwork competencies, problem-solving being the most mentioned. On the other hand, the exit survey ES indicated that teamwork was the most developed competency during the activity. Indeed, students recognized the importance of teamwork in the solution of the problem, and they stated in the survey that they had developed fundamental skills such as tolerance, resilience, effective communication and coordination of activities under pressure, among others.

The students perceived the activity as challenging and indicated that it met their expectations (the acquisition of Csp and Ctc competencies), which validates the It model, in this case, for the development of those competencies. On the other hand, students also indicated in this survey that they would be able to apply the knowledge acquired in different contexts, suggesting that this educational model develops in them skills that facilitate their transition to life and, therefore, the relevance of *IT*. In addition to being a tool for the development of skills, *IT* allows the student to acquire knowledge in areas different from his or her specialty and opens the possibility of promoting different values in the students (e.g., social commitment), by linking the designed challenges to current social issues.

Future work considers the development of new *IT* activities with different combinations of variables: campus CPS; curriculum CARR; semester SEM; team EQ, with different scenarios and competencies to develop to understand better the impact of this model on the development of competencies in students. Besides, the monitoring of students after they graduate and the measuring of their success in entering professional life would produce important data that could finish validating the model and its relevance to the new and changing demands of the work world.

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Appendices:

Rubrics used for the assessment of the challenge

Rubric P

The Bread (30 %)	
Flavor	
Aroma	
Appearance	
Texture	
Color	
Size (Individual Portion)	
Percentage increase in bread mass from the original size	 Deficient Adecuate
Nutritional Value	 Low High
Cost	 Low High
Comments:	
Final Grade for Bread:	

Rubric H

The Oven (25 %)	
Functionality It is easy to put in and take out the dough from the oven; the doors open and close easily. It is easy to turn on.	 Difficult to operate Simple to operate
Safety It is easy to light the oven; there are no combustible fumes, the possibility of being burned is low	 Dangerous Safe
Efficiency The oven efficiently uses energy. The elements guaranteeing the oven's thermodynamic efficiency are shown.	 Low efficiency High efficiency
Comments:	
Final grade for the oven:	

Rubric C

Contamination (15 %)	
Combustible Gases Indicators are present that show the level of contamination the oven is generating. Reference is made to international indices or Official Mexican Norms (NOMs).	 Very contaminant Little contaminant.
Implements of Reduction Some device has been implemented to reduce contamination.	 No Yes, functions adequately.
Comments	
Final Grade for Contamination:	

Rubric E

Alternative uses of unused energy in cooking (15%)	
Heat not used for cooking bread has a viable alternative use.	 There is no proposal Yes, and it is viable
The proposal submitted for the use of lost heat solves some real problem.	 It doesn't resolve Yes, there is relevant resolution
The proposal is economical, accessible, and durable.	 No Yes.
Comments	
Total (Alternative Uses)	
Final Grade for alternative uses of heat rubric	

Rubric AE

Self-Assessment	1	2	3
Punctuality	I arrived late most of the time, or I missed some of the meetings.	I arrived punctually at most of the meetings.	I attended all the meetings punctually.
Cooperation with the group	Little or none	I cooperated with what was assigned to me.	I took the initiative; I helped with everything that was asked; I was available.
Task Accomplishment	I didn't perform on time with one or more of the assigned tasks	I completed most of the tasks assigned on time.	I completed all the assigned tasks on time.
Attitude	I wasn't willing, or I was intolerant most of the time.	I was willing and tolerant most of the time.	I listened, observed and participated with understanding, tolerance, and empathy, always seeking the common good of the group

Rubric CE

Co-evaluation	1	2	3
Punctuality	Unjustifiably missed some of the meetings and/or was late on more than one occasion	Missed some of the meetings or arrived late.	Punctually attended all the team meetings and was ready to work.
Responsibility	Did the minimum necessary and/or did not attend prepared or with the assigned materials	Sent his work or material in his absence or was distracted during the sessions	Worked diligently (arrived prepared with work/assigned material, did the job in the best way)
Contribution	Don't do their part or very little or very poorly.	Did their part but processed the information very little.	Provided valuable information or work exceeding expectations.
Collaboration	Did not support the team and/or only imposed their ideas.	Did not share; accepted others' ideas in a very limited way.	Shared and accepted other points of view, ideas, and suggestions.
Attitude	Didn't listen to others; criticized others negatively; wouldn't apologize when he was late.	Acted respectfully but distant from others.	Kind behavior; listened to, observed and participated with understanding, tolerance, and empathy, always seeking the common good of the group

Rubric TC

Collaborative work (Teamwork)	1	2	3
Roles defined	Roles are not defined.	The team roles are not clear.	The roles of each team member are very clear.
Team Integration	The team is not integrated.	The team is not well integrated.	Perfectly integrated.
Commitment	No commitment	Little commitment	Very committed.
Communication	The team does not communicate well and/ or work independently	The team members communicate.	The team members effectively communicate with each other.
Problem and conflict resolution	The team does not resolve presented problems	Regularly solves problems	Great capacity for solving problems that present themselves.
The team accomplishes on time what is required.	No	Moderately, fairly	Yes
Social Empathy	Its design, scope do not contemplate the good of the Institution	Its design, scope contemplate very little the good of the Institution	Its design, scope contemplate clearly the good of the Institution.