Theory of multiple intelligences applied on teamwork with intervention under Challenge Based collaborative Learning strategy for improvement of online learning.

J. Ángeles Islas
Escuela de Ingeniería y Ciencias. Tecnologico de Monterrey 64849, NL (México)
(Corresponding author: jorge.angeles@tec.mx)

J.J. Franklin Uraga
jjfranklin@tec.mx
Escuela de Ingeniería y Ciencias. Tecnologico de Monterrey 64849, NL (México)

P. Ortega Pérez
paloma.ortega@tec.mx
Escuela de Ingeniería y Ciencias. Tecnologico de Monterrey 64849, NL (México)

A.E. Juárez-Hernández
aejh73@gmail.com
Instituto Politécnico Nacional, GAM-CDMX, C.P. 07340 (México)

Abstract
In the present work, the individual learning results are contrasted in two groups of first-semester engineering students who teamwork under Challenge Based collaborative Learning strategy in online sessions. The deliberate intervention of the teacher on the selection of participants is proposed, forcing the integration of each team with students who have different predominance over any multiple intelligences, which favors an assertive dynamic and heterogeneous collaborative interaction among participating, who consolidate individual learning. The result is based evaluation is summative and based on specific criteria. The level of competences and in general implicit and explicit learning is evaluated. The results show that individual learning in participants of teams with intervention is favored over those not intervened, achieving an increase in the average evaluation.
Keywords: Collaborative work, Challenge-based learning, Theory of multiple intelligences, Online Learning.

Introduction
Teamwork between students during their university training is a common practice which it is expected to consolidate an integral part of learning through research work, creative activities, development of presentations, among others, in order to introduce the student to a scenario that allows improving professional skills on a variety of possible settings. In engineering areas, in the first semesters, teamwork tends to be developed between students who take the same subject through team building. Teams are usually made up of grouped participants without criteria or reasoned intervention. Collaborative work within teams with the aim of developing an activity or solving a specific problem represents a valuable approach to learning based on collaborative work (Maria Margarita Lucero, 2003). Team activities represent an individual opportunity for the student to learn to socialize, expose and defend ideas as well as mature their argumentation skills, triggering implicit and explicit learning, which favors the development of competencies focused on the performance of the individual in their environment (Valiente Barderas, et al, 2009), area that currently positions educational research and its methodologies in a scenario of great reflective and research activity in various institutions in Mexico and the world (Tejada Fernández, et al, 2016). Teamwork takes on formative relevance, when the activity consists of the solution or resolution of a specific challenge, where the team requires concentrating the analytical, reflective, creative capacity as well as the skills to transmit ideas and represent them for others, manage the work between participants as well as the self-management of individual learning (Gilbert Delgado et. al. 2018, Silvia Olivares et. Al. 2018). We associate various teamwork problems with the inability to collaboratively solve various aspects related to the diversity of bio psychological potentials present in each participant, in such a way that the absence of significant weakness of any of these within a team, it can limit collective achievement and undermine the potential of the strategy. We use Gardner's conceptualization on the presence of Multiple Intelligences MI (Gisela Emst-Slavit, 2001),

extended for learning scenarios at the university level, particularly in engineering, under the premises of the theory, namely: 1.- In general, each person develops several MI at some level, 2.- All MI´s in each person participate in a joint way and complex, 3.- Each person can develop some MI to an appropriate level of competence, 4.- Each MI of a person can be enhanced by specific experiences. Basic exploration carried out, indicates that the creation of teams without criteria, very frequently produces teams where certain types of individually predominant MI dominate, when it comes to specific professional profiles. The MI are cultivated throughout the life of each student and are not permanent when they are stimulated appropriately according to the theory of cognitive neuroplasticity, so they can be enhanced in each individual in such a way that the reinforcement of one and the improvement of others, it is per se a favorable learning condition when developing individual competencies to obtain an achievement, solution or a common product through teamwork. The research developed in the present work consists of evaluating individual learning, by favoring deliberate intervention in the integration of students in a team through a selection process based on a test to identify the predominance of some MI from each participant. The objective of the intervention is to create teams with students of different predominant MI. Specifically, for the purposes of the experiment, two groups of teams are generated, the first consists of teams whose members have been selected without criteria, we call this group Teams No Intervention (TNI) and in the second, each participant in a team has a predominance in one of the MI and different from the rest of the members of their own team, we have called this group of teams with intervention (TWI). Both groups undergo the same teamwork under Challenge Based Collaborative Learning Strategy (CBCLS) and the individual learning of each member is conventionally evaluated to validate the following hypothesis in the described scenario.

Experimentation scenario

From two prestigious institutions in Mexico, namely Instituto Politécnico Nacional-México and Tecnológico de Monterrey-México, students of equivalent subjects (related to thematic contents of classical mechanics in physics) are selected. Participating students attend between the first and third semesters in their respective institutions. The research is carried out during the period of the usual semester, which has an average duration of 5 months, and is carried out in virtual session. The results of the activity are obtained at an intermediate point in the semester.

Hypothesis:

There is a positive influence on learning assessment results when working in TNI or TWI.:
Null hypothesis : The type of team in which one participates during the CBCLS does not influence on the result of learning evaluation.
Alternative hypothesis: The type of team in which one participates during the CBCLS influence on the result of learning evaluation.

It is desired to establish a significance level of 5% on the research hypothesis to consider it relevant.

Methodology

About evaluation

Individual learning is evaluated through a conventional written evaluation that addresses conceptual aspects and operational and quantitative analysis, as well as another oral-argumentative team evaluation in order to record the concrete learning of thematic contents and validate the presence of specific disciplinary competencies for engineering. The latter is evaluated by professors with teachers in the areas of mathematics, physics and programming.

Studied Sample Generalities

92 newly admitted students (first and second semesters) to engineering were selected, who joined the Tec 21 model of the Tecnológico de Monterrey-Campus Hidalgo-México (ITESM), in the month of August 2020 to study in a remote mode. The aforementioned model incorporates the CBCLS, which is developed in a modality of three blocks with duration of 5 weeks each, developed in a school semester. At the end of each block, an argumentative evaluation is made to each team with aspects related to the resolution of the response in consensus of the evaluating teachers on thematic contents. Additionally, 79 students from the Instituto Politécnico Nacional-Mexico (IPN) are selected, also in the first and second semesters of engineering, enrolled in the UPIITA-IPN- Mexico. In this Institution, the courses are also with thematic content of physics for engineering (Classical Mechanics), in this case, the global evaluation results from the arithmetic average of three partial evaluations distributed in periods equivalent to the duration of ITESM blocks throughout the semester. Development is proposed in similar times and formats simultaneously in both institutions. Finally, because in the IPN the evaluation is not between two or three professors, the collaboration of an assistant professor is requested in order to standardize the argumentative evaluation format.

Experiment overview

The total number of participating students is 171 with ages from 18 years (see figure 1), in this sample, 67% of the total come from public schools and the rest from private schools; in all cases in Mexico. 45% are women and the rest are men, the graduation averages range from 7.2 to 10 on a scale of 0 to 10, in the case of participants who come from upper secondary schools where their score is 0 to 100, their Average is divided by 10 in order to standardize the scores for statistical analysis purposes. The density of teams and members studied in the present work are distributed according to Table 1. According to the results of the exploration of predominance in individual MI, it is impossible to include all the participants in TWI. As many teams as possible are selected under the intervention criteria and the rest are left to configure without intervention to obtain the TNI group. Is possible assumed that this biases the study by predisposing to the integration of the latter with deficiencies in the density of MI due to the assembly of TWI, however, the research objectives are met by being able to visualize the learning contrast between one and the other.

Table 1 *Number of participants and teams configured with and no intervention in both institutions (ITESM and IPN)*

Institution	Total participants	TWI (6 members) Equipment	ESI (6 members) Equipment	Number of team members not participating in the experiment
IPN	79	5	7	7
ITESM	92	7	8	2
TOTAL participants	171	72	90	9

To determine the prevalence of MI, it is requested to the student to answer a standard test based on multiple intelligences theory, namely: Mathematical Intelligence (MI), Kinesthetic Intelligence (KI), Verbal Intelligence (VI), Musical Intelligence, Spatial Intelligence (SI), Intrapersonal Intelligence (Intra), Social intelligence (SI) and Naturalist Intelligence (NI). (Thomas Armstrong, 2006). The responses are recorded; the participants are classified and distributed in each team to obtain the TWI group.

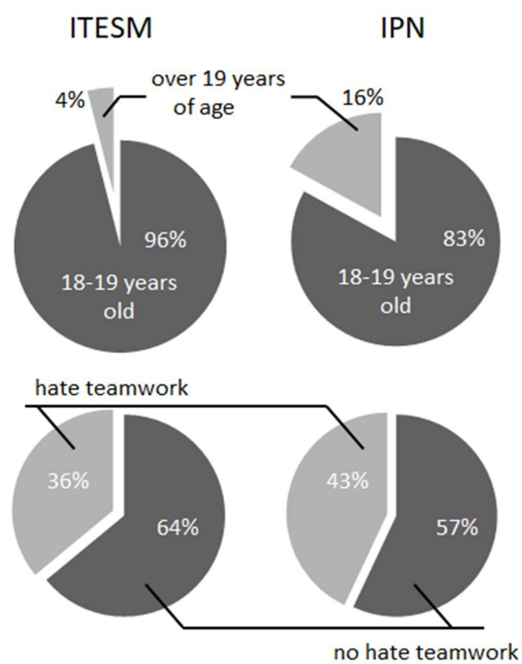

Figure 1: Percentages relative to the total number of participants from both ITESM and IPN institutions. In pie format (upper part) percentages of ages of the participants, in the lower part, percentage of participants who consider it a good experience teamwork or collaboratively.

It is known that there are 8 different MI types, however, in the present work no student was considered mostly naturalistic at least in this sample, this result is atypical, but it may be explained by the fact that the participants in this study have strengthened MI's aligned to your profile, however the latter is conjectured and requires a higher data density analysis. On the other hand, the interpersonal and intrapersonal intelligence profiles have been united assuming that both have the ability to manage their own emotions and, on the other hand, the ability to socialize, which contribute to the resolution of personal conflicts and harmonize the work within. During the experimentation we work with a condensed classification of 6 intelligence profiles with an achieved distribution shown in figure 2.

The disparity in prevailing MI densities is notable. The high density corresponding to MI is understood due to the engineering profile of the sample. Another observation of interest results when comparing the percentages in each MI by institution, in the case of the IPN, a greater self-perception of the MI potential is notable, however in the ITESM, the distribution seems greater for the case KI, VI and M , The above could be related to the admission criteria, considering that the number of ITESM students enrolled in sports and artistic expression activities is greater, while in the case of the IPN admission criteria they are exclusively academic. The results offered in figure 2 are descriptive of the sample and not inferential in the strict sense.

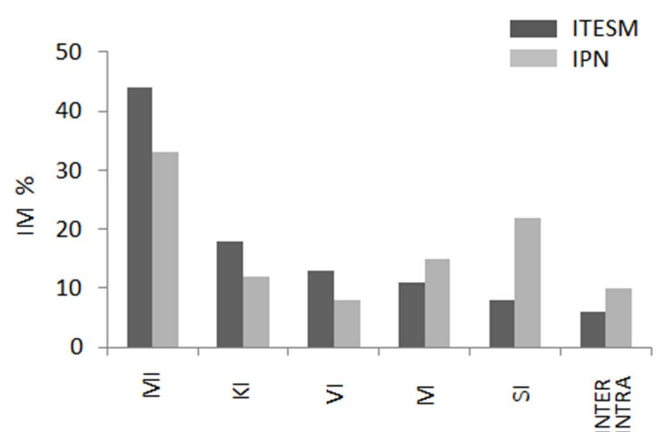

Figure 2: Percentage distribution (ordered from highest to lowest in the case of ITESM) about the perception per student about their predominance in any of the multiple intelligences (MI) in all participating students from both institutions (IPN and ITESM)

Development of the experiment

The experimentation was carried out in a format equivalent to a double blind test, in which participating students and teachers acted in complete ignorance of the research, only participating students were notified of the predominant MI test. Due to the number of intelligences condensed for the purposes of the work, each group is expected to have at least 6 members. The combination of intra- and SI, allows a participation density of 12% for the ITESM and 18% for the IPN. A difficulty in forming teams is associated with the number of participants, some teams formed after obtaining all possible TWI and TNI, will have fewer members, but these represent a small number and have been discarded from the desired contrast study. Finally, the results are analyzed separately for both institutions in order to avoid bias in the interpretations that result from a subjective component related to the perception that each teacher may have during the argumentative evaluation. The complication in obtaining TWI associated with the number of participants could be solved by developing sufficient CBCLS activities by rotating participants.

Generalities about the proposed challenge

A challenge aligned with the Tec 21 model was selected for the TCBR, which consists of determining comet orbit given its eccentricity and the straight-line distance to planet at time when the asteroid is eclipsed by the sun. In this scenario, it is also sought to evaluate the probability of collision with planet earth. In this context, it seeks to incorporate the conceptualization of competences assessment aligned to the approaches generated at the higher level both in Europe (Cano García et. al , 2008) as in Mexico, trying to include the teaching skills. Innovation, adaptation and construction of scenarios for learning in distance and flexible models is required on the evaluation (Blanca Valenzuela. et. Al, 2013, Frida Barriga, 2019); particularly in the case of the incorporation of the evaluation of the competence seen as integration of complex knowledge (Daniel Ríos Muñoz, 2017), accepting that the competencies are an assembly with complex interactional dynamics between elements (Aurelio Villa. et al, 2011), which gives relevance to the value of the TCBR. Without omitting the areas of opportunity related to the evaluation through rubrics with specific indicators useful to effectively validate the presence of the desired competencies (María Espinosa, 2013).

The aspects of interest of the challenge are recovered from aspects raised by various specialist teachers in the areas of Physics, mathematics and programming, and cover aspects related to expected disciplinary competencies in the engineering areas, which are condensed in table 2.

Table 2 Specific *skills that are expected to be developed during the TCBR which are raised by consensus among physics, mathematics and programming teachers and that are aligned with the main disciplinary competencies required in the engineering profile.*

Disciplinary competence	Skills assessed
Math	Construction and interpretation of mathematical models with a diversity of approach, mathematical Interpretation of results, analysis several variables, quantification of physical phenomena, deterministic approach and interpretation of graphs, data, maps and diagrams
Experimental sciences	It establishes interrelationships between science, technology, society and the environment, bases opinions, obtains and analyzes information to ask or scientifically explain an aspect, analyzes laws and finds associations between different areas of knowledge, as well as assesses conceptions and groups on scientific aspects.
Social	Identifies learning and knowledge as well as social culture associated with the understanding of a phenomenon and its relationship with the interests of society, analyzes with entrepreneurship the impact of scientific solutions in society, analyzes the relationships between social activity, and its powers with the resolution of a social problem or that impacts its development, establishing the relationship between the political, cultural, economic and geographical dimensions of an event
Communication	Select order and interpret ideas or explicit or implicit data

Under the challenge scenario, dynamic between members of the same team is favored during the CBCLS that generates an interaction between skills of each profile of the different MI with the maturation and even obtaining of skills that complement or extend the set of existing ones in each participant. Rubric 1 (table 3) is proposed for purposes of argumentative evaluation, to distinguish specific competences. The aspects to be evaluated are carried out in consensus with teachers who have had experience for more than 10 years in front of the group (not necessarily the participants in this experience). The evaluation is obtained during the oral presentation by each team in the presence of teachers. Each aspect evaluated aims to explore components related to the mentioned MI. The evaluation scale used is polar Likert with criteria: *poor, regular and outstanding*.

Table 3 *(Rubric 1) Aspects to be evaluated on the performance of participating students from both institutions (IPN and ITESM) in ECI and ESI. The rubric is answered during CBCLS when presenting their challenge resolution.*

During the presentation of the resolution of the challenge in teams (the students): Competency-Based Evaluation			
1.- **(EOC)** They correctly established and addressed the objectives of the challenge	2.- **(TACC)** They took advantage of the conceptual diversity involved in the challenge theme	3.- **(VMR)** They used valid mathematical representations	4.- **(OVS)** They offered descriptive videos with good content and structure
5.- (DAR) They formally described the approach of their resolution	6.- (OAI) They offered an appropriate info graphic presentation	7.- (PAV) They presented auditory and visual aspects that help the transmission of ideas	8.- (OPD) They offered phenomenological descriptions related to the challenge

Teacher intervention

The level of approach of the student to the teacher during the CBCLS, is evaluated with the survey of participating teachers (condensed in table 4). Aspects are explored where participants from both TWI and TNI groups require greater accompaniment from teachers, under criteria related to good teaching practice (Ted T. H. POON, Joseph W. C. LAU, 2020).

Table 4 Aspects *where the students most frequently requested the teacher's support during the resolution of challenge in teamwork*

The student requested support from the teacher in:			
1.- **(SMA)** Specific mathematical aspects	2.- **(CPC)** Clarification on Physics Concepts	3.- **(OTD)** Organization for the teamwork development	4.- **(OWP)** Organization for the work presentation
5.- **(UAO)** Understanding the activity objectives	6.- **(ATAC)** Where and how to inquire about thematic aspects of the challenge	7.- **(HSR)** How solve challenge because they failed on the resolution	

After the CBCLS activity, the participants of both groups (TWI and TNI) are asked to answer a survey (Table 5) to explore results that allow contrasting the perception of learning obtained with the activity (polar Likert scale based on responses; *nothing, little, greatly*).

Table 5 *Survey applied to students to explore their individual learning perception*

In general your experience in teamwork during the resolution of this challenge:		
Improves general learning	Helped improve ability to propose, argue, explain and defend ideas	Helped to connect and integrate with other ways of thinking and really get a team solution.
Learn through another or other students, things that you did not know with an approach that you had not considered before		Learn through concepts, mathematical skills and holistically your effective learning

Finally, an individual written exam is carried out with theoretical, conceptual and mathematical skills aspects to evaluate the operational and conceptual learning achieved in each student and contrast the impact of the CBCLS on individual learning achieved in the TWI and TNI groups.

Results and Discussion

Results obtained are grouped into a graphs series in order to show relevant contrasts aimed at evaluating the hypothesis under investigation.

Before and after the CBCLS, the perception of the liking of teamwork is evaluated and the results are presented in Figure 3, in these results a change in perception, particularly in the case of the TWI, where there is a uniform increase in participants who perceive teamwork as a good experience after CBCLS, while in the case of the TNI, a less relevant improvement is registered. The least favorable change in the perception of liking for CBCLS in the TNI can be associated with the reduced diversity of MI within the teams.

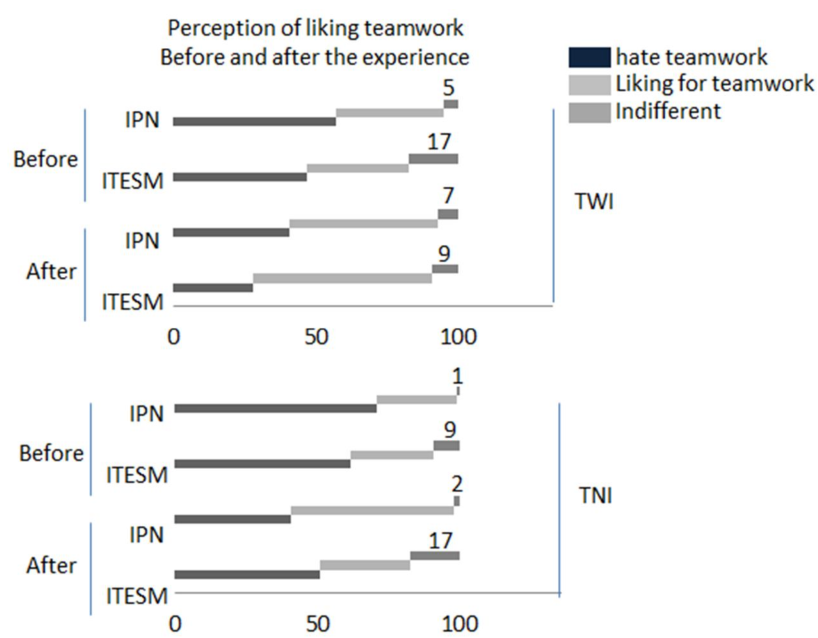

Figure 3: Fractions of participants who do NOT like teamwork (extreme left horizontal bars), who like teamwork (bars in the center), and those who are indifferent (extreme right bars). Perceptions before and after the experience are from both sets of ECI (top) and ESI (bottom).

On the other hand, the evaluations obtained by the team based on the survey (table 4) are grouped in figure 4. These results show sensible changes in the teacher's perception regarding the achievements and in general the quality of the presentation as a result of the CBCLS. Although the quantity of TWI is different from that quantity TNI, the relative percentages are notably higher for the outstanding evaluation in the set of TWI; such is the case of the DAR aspect in which the set of TWI achieves 50% in contrast to the 33% achieved by the TNI. The foregoing leads to establish that during the CBCLS in remote mode, successful results are achieved in the set of TWI. Therefore, the intervention effort to include MI diversity in the TWI group favors collective achievements.

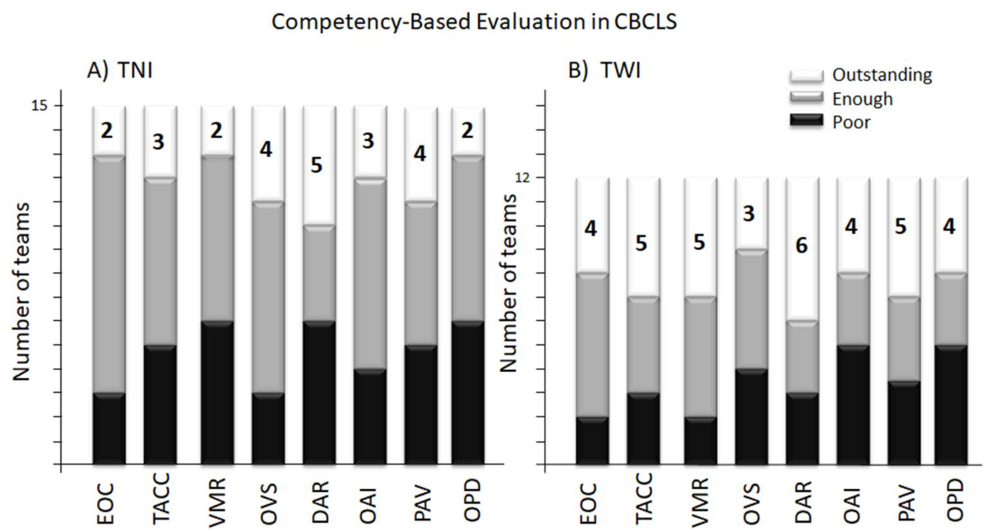

Figure 4: Survey results (table 4). In A) No intervention and B) with intervention. The results are presented for both groups of teams obtained from all participants from both institutions (IPN and ITESM). The number in each bar represents the number of teams achieving the outstanding evaluation

Regarding the level of intervention from teachers, the results obtained are condensed in Figure 5 where the type of intervention is shown according to the survey (table 4) vs relative frequency percentage of participants which requested specific help.

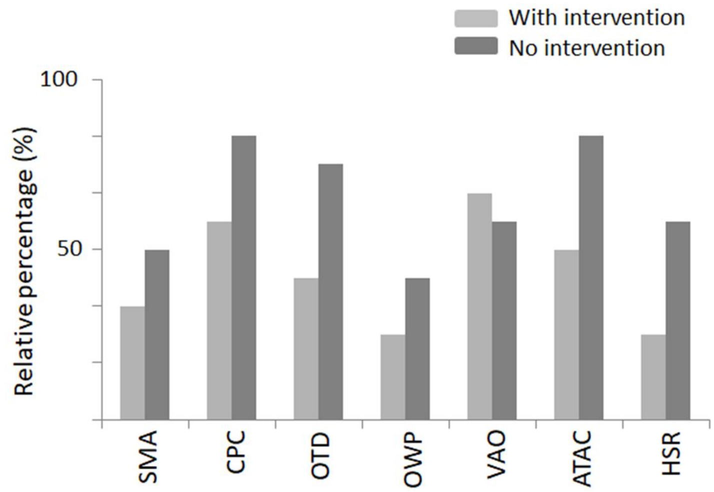

Figure 5: Relative percentage record with level of teacher intervention during the development of teamwork on solving the challenge, obtained according to the survey (table 5).

Graph (figure 5) shows a higher frequency of requests to teacher approach by students (registered in terms of the relative percentage perceived by teachers), in order to solve specific aspects (table 4). Only in the VAO aspect does the TWI set surpass the TNI set. The explanation is not obvious, however it may be associated with a greater intra-group discussion within TWI related to the diversity of MI, which could be assumed as a result of the strong predominance that each student has and that may lead to reasonable doubts of the scopes or personal interpretations of the objectives to be achieved collectively during the TCBR. On the other hand, in the rest of criteria, a significant decrease is seen in the TWI group, which is associated with better learning management when participants with predominant MI diversity are involved.

Statistical analysis of results

The global evaluation results from the average of a score from zero to 10 resulting from the argumentative evaluation by team based on the rubric (Table 3), however, depending on the level of participation and individual responses during the presentation; the panel of teachers can individually penalize a student with a lower grade than the team. The remaining grade to achieve the average is obtained individually through the written exam by each participant with a scale also from 0 to 10. The average of the evaluation is given in numerical format. The quantitative results obtained by the students during the TCBR experiment for both groups, TNI and TWI, are classified in three levels, as shown in table 7.

Table 6 Frequency of participants who have obtained scores on a scale from 0 to 10, classified into three intervals and achieved during experimentation with intervention and no intervention.

	Grade ≤7	**7< Grade <9**	**Grade ≤9**	**Total**
TWI	16	48	8	72
TNI	41	36	13	90
Total	57	84	21	162

Note: The total number of participants is 171 but, as previously established, 9 students in the sample did not participate directly in the results analyzed.

According to the results of Table 6, the theoretical frequencies for each subset of each interval are obtained in such a way that: $\chi^2_{Calculada} = \sum \frac{(f - f_{teórica})^2}{f_{teórica}}$, which in our case is $\chi^2_{Teórica}$ = 12.0, while with two degrees of freedom and a margin of error of 0.05 $\chi^2_{Teórica}$ = 5.99, in this case $\chi^2_{Calculada} > \chi^2_{Teórica}$ so it is rejected H_0 so student participation in TWI o TNI influences the outcome of your evaluation.
The standard statistical treatment for a normal distribution, applied to all the data obtained per participant, generates the following results (sample analysis, table 7):

Table 7 *Evaluation results and their respective statistical parameters for the two groups of teams studied. Column A) TNI and column B) TWI (Remaining students have been discarded)*

Sample analysis	A) TNI	B) TWI
Sample size	90	72
Arithmetic average (μ)	8.31	8.99
Sample variance	1.1043	0.6082
Sample standard deviation	1.0508	0.7799
Confidence interval (95%)	8.09 - 8.53	8.81 – 9.17

We can affirm that there is a 95% certainty that the average obtained by students within TWI will be between 8.85 and 9.13. In the case of TNI, we can establish that the average of the participants' grades will be between 8.09 and 8.53, which represents a numerically smaller range of grades with respect to the TWI. This implies that in effect the intervention of teams with criteria based on Gardner's MI theory that has a favorable impact on the individual learning of the participants.

Conclusions

Results show that there is influence on individual learning when works teams are deliberately created under the criteria of inclusion of the diversity of dominant MI under a distance learning scenario (generated by the current pandemic) under the TCBR strategy. The results show that the strategy, despite being applied in a virtual scenario, offers an evident improvement in the individual perception of learning and in the perception of the evaluating teachers panel on the obtaining or presence of skills associated with the expected competencies in engineering students on TWI with respect to the participants in the TNI. Therefore it is relevant that students work together with other students with different predominant MI. The inclusion of this practice contributes significantly to CBCLS strategy can be more effective not only when it comes to a common achievement, also when it comes to individual learning, the students of TWI benefit by growing on others MI. The strategy offers an interesting scenario that favors development in each participant, thus generating not only concrete learning, also the robustness of diverse skills, which to a lesser extent is achieved in the case of students of TNI.

The way in which the amount of help requested from the teacher in TWI group in contrast to the TNI, it is clear that in practically all categories, TWI students to have a greater understanding of the concepts required to be able to attend to the several stages of the challenge to be solved, which allows to conclude that the integration of various MI profiles contributes to the fact that the lack of mastery on topics by the participants can be solved through the management of learning among the teams members. The sum of potentials associated with the predominant individual MI adds up through each participant in the TWI, generating a greater resolution potential for the team. The fact that the TWI tend to consult more about the objectives could be related to the fact that different profiles of predominant MI also translate into different perspectives of what each one understands as essential to solve in the assigned challenge. The results suggest that the fact of working in TWI enhances individual learning, possibly due to the strengthening of other intelligences when is applied the CBCLS strategy complemented with the intervention strategy suggested here, may not only develop the disciplinary and transversal competences included in the design of each subject, would also favor the comprehensive development of the student that outline their professional interest during the course of their subjects, either in online mode or even to be extended to the presential mode.

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