Developing Reasoning Competencies in a Short Introductory Engineering Physics Course

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Abstract* - This Innovative Practice Full Paper presents the implementation of a scenario posed to freshman engineering students taking an Introductory Physics short course related to Kepler's Laws for planetary motion. The objective is to guide them to structure a coherent explanation for this scenario. The above is part of the realization of a new educational Tec21 model that Tecnologico de Monterrey has started, where the whole curriculum is focused on challenge-based learning. The emphasis is given to the development of student competencies when real-life situations are faced, in contrast to traditional lecture-based programs. In order to evaluate the student achievement of this competence, a final exam was applied including both standard end-of-the-chapter problems and questions that required higher argumentative thinking levels. The latter was aimed to assess the reasoning followed by students when prompted to analyze different situations from an initial standard context. For a sample of 319 students, it was found that students overall got grades about 20% smaller in the argumentative questions, as compared to the knowledge questions. This can be explained in part due to the fact that most students are only beginning to develop such higher level reasoning and thinking competencies. These results suggest the need to design learning strategies to reinforce the students' reasoning processes.

***Keywords*— competencies evaluation, educative model, learning physics, reasoning competencies,**

I. Introduction

In a traditional educational system, Physics, Chemistry or Math are usually taught as seperate disciplnes. Even though math is the language of physics, and the strong connection between Physics and Chemistry, every effort in order to integrate those subjects was isolated and taught only from the professor's point of view. The relevant part of the traditional model was in the disciplinary contents. However, nowadays, with the advancement of technological platforms and the power of the Internet, the access to information is closer than ever, and the authorities of the Tecnológico de Monterrey agreed that the current undergraduate education paradigm *must* change.

The Tec21 Educational Model was implemented for the first time in the Fall Semester of 2019 at all campi of Tecnologico de Monterrey. The core of this Educational Model follows an out-of-the box process, in which these disciplines are related to each other by facing the student with a *challenge-based learning* process [1].

The new Tec21 Educational Model is based on the development of *competencies,* both *disciplinary and transverse,* providing students a memorable well-rounded education [1], [2]. For Tecnologico de Monterrey, the gist of a competence contains 3 main characteristics: (a) the integral behavior of a student from beginning to end [3], (b) the conscious integration of attitudes, values, abilities, roles, responsibilities and knowledge to perform *intentional* behaviors in specific contexts [4], and (c) the contextualized *know-how* related to an integral education contributing to the education of sensitive, inquisitive and ethical human beings [5]. Core competencies in the Tec21 Educational Model are called *disciplinary competencies*, that is to say, those that are related to the main contents of the academic area. On the other hand, *transverse competencies* are the common ground abilities that are required by all our grad students in all academic areas.

The Tec21 Model defines 7 transverse competencies: *a)* self-knowledge and management, *b)* innovative entrepreneurship, *c)* social intelligence, *d)* ethical commitment and citizen engagement, *e)* reasoning for complexity, *f)* communication, and *g)* digital transformation [6]. For their development, both disciplinary and transverse competencies break down into smaller pieces called sub-competencies. Not only must the knowledge be passed on, but also, systematically questioned, applied and then expanded into new horizons. In the Tec21 Model, the acquired knowledge in a given course is immediately applied on *ad-hoc* designed *challenges* so that students experience for themselves the relevance of different disciplinary areas at once. In this sense, a challenge is a real-based project intended to gradually develop the above student competencies [1], [6].

As exemplified in Fig. 1, one important feature of the Tec21 model is its flexibility. Instead of choosing a major from the beginning, the student enrolls in a general *Avenue* (which comprises several related majors) from the following: *a)* Applied sciences, *b)* Chemical processes and bioengineering, *c)* Innovation and transformation and *d)* Computational sciences and information technologies.

During the first 2 semesters, the student has the opportunity to change avenue if she later realizes that something else is of interest [7]. All avenues have 3 stages: *a)* The *Exploration stage*, in which the foundation of the professional path is settled and all the students in a given avenue take similar courses, *b)* The *Focus stage*, in which the student chooses a specific major within the given avenue, and *c)* The *Specialized stage* at the end, in which students take advanced tailored courses aimed to train them in a particular major concentration [7].

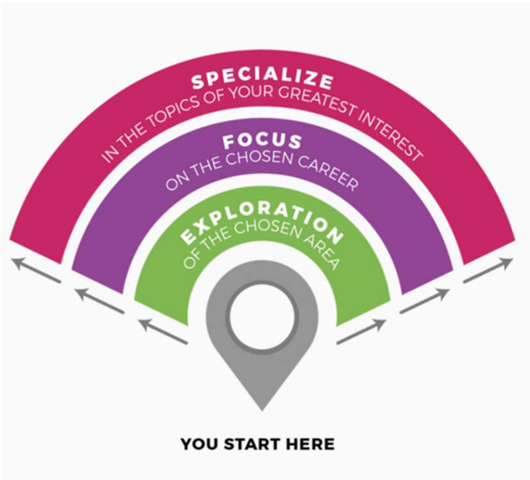

Fig. 1 The three phases of the undergrad careers at Tecnologico de Monterrey

Tec21 Model deals with *Formation Units* such as Courses, Blocks, *Tec-weeks* and *Tec-semesters*. Canvas is used as the basic Learning Management System. As mentioned before, the Tec21 model is based on *challenge-based learning* so that the students' learning process throughout their undergrad studies is centered on the student's involvement with their professors and the environment by solving the posed challenge [8], [9]. In this way, students develop transverse and disciplinary competencies through the solution to real problematic bonded challenges, and by proving the advancement of their knowledge by means of different learning evidences. In this model, *challenges* are the central learning gist.

A Tec21 *course* can last 5, 10 or 15 weeks and it is taught by one professor. A *block* is a more complex formation unit, which is taught by a group of 2–4 professors from different disciplinary areas. For the Engineering and Science School, these areas include a physics professor, a math professor, a computational-area professor and an "avenue" professor [1], [7]. The latter, is the one that adds the spark of specialization to the assigned challenge. This team of teachers lead the path to the challenge solution and they are also responsible for the development of student competencies. During the first 2 semesters, the blocks last 5 weeks, with 12 hours per week of active instruction and collaborative work.

Each semester lasts 18 weeks. In particular, the first semester of the Exploring stage is organized as follows: during the first 5 weeks, the **F1001B block** (*Engineering and sciences modeling*) is worked out [10]. Each week, a different *small challenge* corresponding to the 4 avenues mentioned above is addressed. The main goal of the F1001B block is to give to the student a sample taste of what is yet to come. In the first week, the main characteristics of the Tec21 model are presented, the Block rules and regulations are also clarified, and students are introduced to general details of their majors. Students also work in detail a wellness program where they are guided through self-awareness and self-knowledge activities aimed to foster an integral human being.

In the second week, the applied science challenge is worked out. In the third week, the student focus on the chemical processes and bioengineering challenge. In the fourth week, the computational-sciences and information-technologies challenge is addressed. Finally, in the fifth week, the innovation and transformation challenge is addressed.

As the student goes through all the different stages along the career, the advancement of proficiency in a number of competencies will be developed until the highest proficiency level (C) is attained. All competencies and sub-competencies are evaluated through *eLumen*, and the student must provide specific individual evidences in each Block.

The main obstacle faced by all professors is to switch from a traditional content evaluation to a newly scheme of competencies evaluation. Eventhough the Tecnologico de Monterrey has implemented a nation-wide Professional Training Program towards this goal, a long path still lies ahead.

The two research questions for this work are: *a)* to analyze how the new challenge-based learning Tec21 model develops argumentation skills and well-structured reasoning in freshmen students, through short argumentative examinations, and *b)* to analyze the student performance in different item categories involving different thinking levels.

In Sec. II, general remarks are given about the challenge-based approach through competencies evaluation. Sec. III describes the methodology, while Sec. IV presents the results and data analysis. Conclusions and future work are presented in the last section.

II. THEORETICAL FRAMEWORK

The Tec21 educational model focuses on challenge-based learning [8] that allows students to face real-world scenarios to generate different solutions in a collaborative way, transforming their environment and adding value to it.

Challenge-based learning has been proposed as a methodology to provide students with engaging real-life problems. Through them, the students realize how the academic contents are merged and focused to provide alternatives of solutions to those problems [8]. In this way, the emphasis is moved from the isolated content memorization, as in most typical courses, to the solution of specific challenges. In the process, multidisciplinary academic knowledge is integrated and students are motivated to provide diverse meaningful solutions for the challenges [9]. In the Tec21 model, the academic progress of the students while solving challenges along their careers is measured through the development of disciplinary and transverse competences.

The term competence in the educational environment is linked to the capacity, ability, dexterity, or expertise to do something specific or deal with a certain topic [11], [12]. In Conceptual Pedagogy, the concept of competence is used to analyze the development of thought [13]. This concept is closely related to training and the way in which mental structures are modified in order to capture a clearer vision of reality. In this sense, competencies can be understood in different ways.

For studies at the professional level in Mexico, the General Directorate of Higher Education for Education Professionals published a document named *Approach Focused on Competencies* [14]. This document describes different meanings of the term competence, depending on the assumptions and educational paradigms on which they are based. The sociocultural or socio-constructivist perspective of the competences is highlighted with a broad conception. The possibility of mobilizing and integrating various knowledge and cognitive resources when facing an unprecedented situation-problem is present. In order to achieve the latter, the person requires the ability to solve complex and open problems in different scenarios and moments. Consequently, the set of criteria on which the competency-based educational approach is based has to be clearly indicated.

Regarding the Tec21 educational model, a competence is a performance that is carried out to solve a specific situation according to certain criteria. In this performance, knowledge, abilities, attitudes and values are consciously revealed in an interrelated and pertinent way [15]. According to this, it is possible to identify if the student has acquired the competencies if she can:

- Consciously carry out an action that satisfactorily addresses or resolves a specific situation.
- Apply knowledge, skills, attitudes, and values to solve or address a specific real-life problem, need, or task satisfactorily.
- Carry out an action in a conscious, intentional and pertinent way, in accordance with expected quality criteria.

There are different classifications of competencies, but for this work the *disciplinary competencies* [3], which belong to a specific field of knowledge or major, are of particular interest.

As mentioned before, one of the most important challenges faced by the teachers staff is the competencies assessment process. The evaluation based on competencies implies, among other aspects, that these must be demonstrated by the student by means of specific types of evidences. This requires the definition of adequate performance criteria that will allow the professor to assign the student a given level of proficiency [16], [17]. Note that this type of evaluation does not exclude the common verification of the theoretical and conceptual mastery that necessarily supports the competence. In this sense, a comprehensive and integrated evaluation of knowledge, skills, attitudes and values in action is required [13], [18].

The disciplinary competencies evaluation process is described below, based on aspects of memorization, and the application of argumentative exams.

III. METHODOLOGY

As mentioned before, the *Formation Unit* **F1001B** "Engineering and Science Modeling" Block is an introductory brief course aimed to give students a first glimpse of typical challenges presented in each of the four main *Avenues* that the student can choose from, after entering to the Tecnológico de Monterrey engineering undergraduate programs. This block comprises a 12 hrs work load distributed along a week. In this work the Sciences Avenue is considered.

The methodology applied in this work is summarized in Fig. 2. The steps are the following: *i)* selection of the *Formation Unit* to be analyzed (the Block), *ii)* definition of the competencies for the Block, *iii)* definition of question categories to be analyzed, *iv)* definition of groups and population, *v)* definition of class activities of the block, *vi)* design of the final student evaluation, *vii)* data gathering and analysis, and *viii)* final results and conclusions. These steps are described in more detail below.

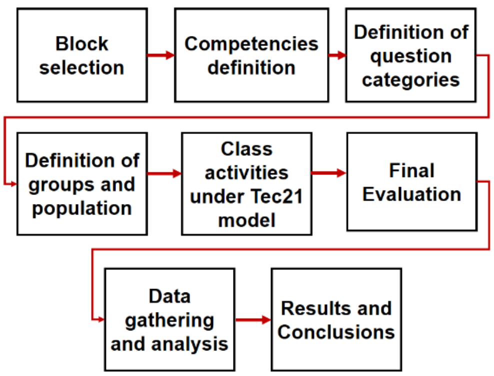

Fig. 2 Methodology employed in this work

A. Block definition and assigned challenge

As commented before, a *Block* is a Formation Unit which involves areas of physics, mathematics, computation and the corresponding *avenue*. In this work, the F1001B block for the Sciences Avenue is considered, which is given by an expert professor in this area. As other formation units of the Tec21 educational model, the block has a challenge (or problematic situation) associated with it, which is the cue that allows professors to introduce the main themes related to the Block. In an ideal case, the assigned challenge will deal naturally with *all* related contents of the block. This fact, motivates the student to understand and apply the different academic contents to the solution of a more tangible situation.

For the Science avenue, the "challenge" posed to the students was a fictitious scenario in which a potential threatening asteroid is seen at the other side of the Sun. Students were given information about its position, period and distance from the Earth and the Sun. Their assignment was therefore to estimate the asteroid orbit and to discuss the probability of a collision with the Earth. This is a perfect scenario to introduce Newtonian gravitation and Kepler's laws, which allowed instructors to examine the reasoning and argumentation skills of the students.

B. Competencies definition

Each block has a set of specific competencies that the student must acquire. For first year blocks, the level is *basic* (level A), while students are expected to reach the highest proficiency level (level C) by the end of their careers.

For the F1001 block studied in this paper, the *disciplinary sub-competencies* to be developed are [10]:

- Sub-competence *SING0101A. Scientific and engineering substantiation.* The functioning of engineering and scientific systems are explained by well-structured coherent arguments based on concepts, theories and principles of natural sciences, math and computational rationale.
- Sub-competence *SING0301A. Problem Solving*. The evaluation of different aspects of a problem based on principles and processes related to the engineering sciences is worked out.

  On the other hand, the *transverse sub-competency* to be developed are:
- Sub-competence *SEG0101A. Self-knowledge and management.* The concept of one's self is established based on an ethical frame of reference, a self-diagnose questionnaire, and a continuous reflection centered on personal and professional growth.

The F1001B block is aimed to develop in the students these competencies at the basic proficiency level A.

C. Question categories definition

As stated in our research questions, the purpose of this work is to study the degree to which students can correctly answer a set of questions demanding different levels of reasoning and thinking. Not only questions requiring memorization of concepts or problem-solving skills are included, but also problems suited to test students' ability to scale a problem to a different situation from which it was initially given, as well as to test their ability to argument their assertions in a structured manner.

To evaluate student performance, we applied a *Final Exam* consisting of 3 types of questions, grouped according to the required reasoning or thinking level:

- *Knowledge category* (hereafter KNO). This category implies questions demanding the student only to remember basic concepts or making simple direct calculations.
- *Application category* (hereafter (APP). This category comprises questions that involve the use of physical laws and their corresponding equations to calculate some physical parameters.
- *Argumentation category* (hereafter ARG), This question category prompts the students to extend their reasoning to predict or to infer the behavior or conclusion regarding a somewhat different situation than those given in application problems.

Each question was graded in a 100 scale and examples of each type of questions are given in Table 1.

TABLE 1. EXAMPLES OF QUESTIONS ACCORDING TO THEIR REASONING LEVEL

Question category	**Examples**
Knowledge (KNO)	What is an astronomical unit (AU)? Find Mercury's semimajor axis in AU given its value in km (unit conversion)
Application (APP)	Calculate Mercury's semimajor axis from Kepler's third law using orbital values for Mercury and the Earth. Calculate the Sun's mass from Earth's period and orbital radius.
Argumentation (ARG)	What would happen to the Earth's orbital period around the Sun if the Sun's mass is increased by a factor 4? Explain your reasoning. If Planet X had twice the Earth's mass value and were placed at the same distance to the Sun as the Earth, what would happen to its orbital period around the Sun? Explain your reasoning.

D. Groups and Population

We worked with a sample of N = 319 freshmen engineering students enrolled in the F1001B block, during the first 5-week period of the August-September 2019 term, at Tecnologico de Monterrey, Mexico City Campus. The students belonged to 11 different sections taught by 3 professors (all of them authors of this paper), hereafter professors *A*, *B* and *C*.

E. Class Activities

The F1001B block was assigned 12 hrs for student work and interaction between the students and the teacher, distributed along a week. Students were organized in teams of 4 – 5 members to find a valid solution to the assigned challenge. During this period of time, the teacher gave some lectures to review Kepler's Laws and the ellipse properties. At the same time, the teacher also supported student work and gave them feedback while solving the challenge.

At the end of the block, the students presented the team solution to the challenge worked by them during the week period. The students gave a 15-min group presentation, during which each student was asked specific questions posed by the teacher related to the solution of the problem. In this way, the professor had elements to evaluate individually the degree of student competence acquisition.

F. Final Evaluation

In the last activity of the block, students were asked to answer an individual written *Final Exam* which tested them about their concepts comprehension related to the solution of the challenge.

The final exam included questions from the 3 categories mentioned above: *a)* knowledge; *b)* application and *c)* argumentation. It is worth mentioning that the related concepts were also discussed during the class sessions along with practical examples. The Exams were graded on a scale of 0 to 100 points. The minimum passing course grade is 70.

G. Data gathering and analysis

We collected data regarding the performance of N = 319 students in the final exam, and we present our data analysis, main results and conclusions in the following section.

IV. RESULTS AND DISCUSSION

After applying the final evaluation to all students of the groups of professors *A*, *B* and *C*, the average grades for each question were calculated. The questions designed by each professor were assigned to one of the three categories mentioned above, being these similar in academic content and difficulty level. The results are presented in Tables 2, 3 and 4 for each reasoning level (KNO, APP, ARG), respectively, as defined above. Each table shows *a)* Question identifier, *b)* Teacher, *c)* Size of the student sample for each question, and *d)* Average grade.

TABLE 2. RESULTS FOR THE *KNOWLEDGE* CATEGORY

Question	Teacher	N	<Grade>
Q1KNOA	*A*	122	83.3
Q1KNOB	*B*	60	96.7
Q2KNOB	*B*	61	76.8
Q3KNOB	*B*	61	85.4
Q1KNOC	*C*	76	60.2
TOTAL	**All**	**380**	**80.1**

TABLE 3. RESULTS FOR THE *APPLICATION* CATEGORY

Question	Teacher	N	<Grade>
Q1APPA	*A*	122	76.3
Q2APPA	*A*	122	85.5
Q3APPA	*A*	122	70.5
Q1APPB	*B*	60	69.2
Q2APPB	*B*	60	49.1
Q3APPB	*B*	60	63.3
Q4APPB	*B*	61	74.4
Q1APPC	*C*	76	66.6
TOTAL	**All**	**683**	**71.5**

TABLE 4. RESULTS FOR THE *ARGUMENTATION* CATEGORY

Question	Teacher	N	<Grade>
Q1ARGA	*A*	122	56.2
Q2ARGA	*A*	122	58.6
Q1ARGB	*B*	61	72.6
Q1ARGC	*C*	76	59.9
Q2ARGC	*C*	76	69.1
TOTAL	**All**	**457**	**61.8**

In Fig. 3, we present a summary of the average grades per category (KNO, APP and ARG) and per professor (*A*, *B* and *C*).

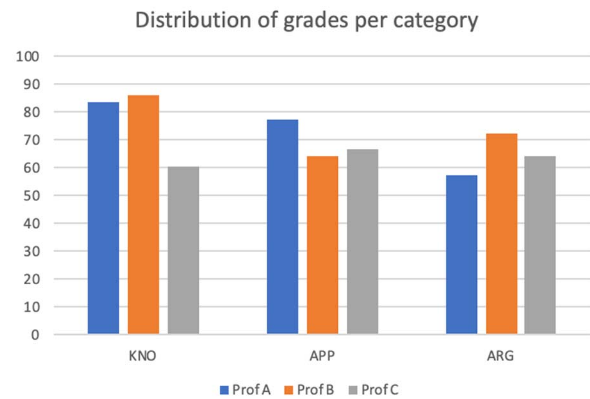

Fig.3. Average grades per category and per professor

From these tables and Fig. 3, it can be seen that the average grade (80.1) is highest for the KNO category, followed by the APP category (71.5), and the lowest average grade corresponds to the ARG category (61.8). On the average, students performed above the passing grade (70) for the KNO category, just barely passed in the APP category, but obtained 8 points less than the minimum passing grade for the ARG category.

It is worth noting, nevertheless, that there are deviations from this overall tendency when analyzing the results for a given professor. While students of teacher *A* have results that follow the general trend with passing grades for the KNO and APP categories, but failing in the ARG category, for teacher *C* the average in the KNO question is *lower* than the averages for the APP or the ARG questions, and there is no major difference between the latter two. For this teacher the average grades were failing in all categories. Likewise, the average grade for teacher *B* is the lowest and failing in the APP category, the highest in the KNO category, and has an intermediate but still passing value in the ARG category.

Even though the questions of a given teacher were properly assigned to one of the three categories, the previous results may reflect the way in which each teacher taught the course, emphasizing perhaps in different ways the course material associated to the different question categories. For instance, teacher *C* dedicated comparatively more time to practice argumentation questions than teacher *A*, and maybe overlooked working with simpler knowledge questions.

A. Analysis procedure

In order to further study the differences in the average grades for each question category, a statistical analysis of the differences of the grades obtained by each student in each question category was performed to determine whether they were statistically significant. The total population of the sample was N = 319 students after joining students from teachers *A*, *B* and *C*. Each student of the sample was assigned a unique grade in each question category: Knowledge, Application and Argumentation. When in an given Exam, there were two or more questions of a given category, the average grade was taken. Table 5 shows the average grades and sample standard deviations for all three professors in each question category.

TABLE 5. AVERAGE GRADE AND SAMPLE STANDARD DEVIATION FOR EACH QUESTION CATEGORY

Question Category	<Grade>	s
Knowledge	79.7	29.8
Application	70.5	29.6
Argumentative	64.0	33.9

A comparison *t*-test of paired sample means was performed, where the results obtained in two different question categories for the same student were compared. First, two-tail tests were carried out with the hypothesis:

$$H_0: \mu_1 - \mu_2 = 0 \quad \ldots (1)$$
$$H_1: \mu_1 - \mu_2 \neq 0 \quad \ldots (2)$$

In light of these results, and with the aim of stablishing an order among the average grade of the three question categories, one-tail tests were also performed with the hypothesis:

$$H_0: \mu_1 - \mu_2 = 0 \quad \ldots (3)$$
$$H_1: \mu_1 - \mu_2 > 0 \quad \ldots (4)$$

The results of these tests are presented in Table 6.

TABLE 6. HYPOTHESIS TESTS

Test	$\lvert\bar{x}_1 - \bar{x}_2\rvert$	t - Student	p-value (two-tails)	p-value (one-tail)
KNO vs APP	9.2	3.08	0.0022	0.0011
KNO vs ARG	15.7	7.13	0.0000	0.0000
APP vs ARG	6.5	4.77	0.0000	0.0000

From Table 6, it can be seen that all differences are statistically significant (with all *p*-values << 0.05). Therefore, these statistical differences show that for the complete student sample, students obtained the best grades in the knowledge questions and the lowest grades in the argumentative questions. In the same way, students overall obtained intermediate grades for the application questions. The average grade for the argumentative questions is about 20% smaller than for the knowledge ones.

B. Discussion

Regarding our first research question, we can mention that the implementation of the Tec21 model is aimed to reinforce, by definition, the development of argumentative and reasoning skills in our students, being this one of the focus aspects in our evaluation process.

Regarding our second research question, these results suggest the fact that Physics students have to follow a progression when acquiring and internalizing new physics models. First, they have to remember concepts and use them in basic situations, then they have to apply them in limited scenarios when solving problems that involve the use of physical laws and equations, similar to typical end-of-chapter problems. Finally, they have to extend and transfer the acquired knowledge to new situations not previously envisaged. Our results suggest that each step requires deeper reasoning and thinking competencies that have to be gradually developed. These results are also observed for traditional Physics courses, according to the teaching experience of the authors.

The effectiveness and pertinence of a course can be assessed through dropout and failing course percentages. In the literature, for introductory college Physics courses, dropout rates have been reported to be as high as 30% due to diverse factors: under preparation in high school, low mathematical background, disengagement, and a lack of motivation and perseverance during the course, among others [19, 20, 21]

Dropout rates in the first implementation of the F1001B block have been observed to be lower (< 5%) than for the first semester introductory Physics courses of the previous traditional model (typically about 10%). This can be explained in part by the fact that students of our sample belong to the very first generation of the Tec21 model and, therefore, most of them enter their programs very hopeful and motivated with the novelty of the model. This block is an overall presentation of the different engineering avenues students can be enrolled to, therefore, it is not expected have high dropout rates in it. It should also be noticed here that the 1-week long F1001B block represents a relatively short time to forsee the true tendency for average dropout rates that other Physics blocks of Tec21 model might have in the future. It can be brought forward, nevertheless, that the first generation of students who enrolled in the following five Physics blocks (5-week long each) during the August-December 2019 and the February-June 2020 terms, also obtained lower dropout rates (<5%) than freshmen enrolled in the previous traditional model at Tecnologico de Monterrey. For the latter, the average dropout rates were about 10%.

On the other hand, regarding the overall student course failing percentage for this block, we found that it is also lower compared to the corresponding one for typical Physics courses of the previous model (< 5% compared to 20-30%). Among the factors explaining this result, it can be mentioned that in the Tec21 model an "oral exposition" aimed to foster student argumentative skills is considered, which tend to increase the final student grade. A more appropriate approach should focus on the comparison between final exam grades rather than on final course grades. Nevertheless, it should also be noticed that it is still premature to compare results from this short one week-long block with a semester-long course. Comparisons with more extended blocks have to be performed as future work. Once again, the Tec 21 model is still very young and students are very motivated and optimistic about the novelty of the program. We have to monitor future student generations to predict the true tendency regarding course failing rates of Tec21 Physics blocks in forthcoming semesters.

The main limitations of this study are the following. First, the block duration of only 1 week (or 12 hrs) is too short for a strong development of the reasoning competencies required for engineering freshmen Physics courses. These have to be built and monitored continuously along all the student career, specially in the forthcoming 5-week long Physics blocks planned for the following terms. Second, the reasoning competences were assessed only through the questions of the 2-hour final exam of the F1001B block. It is suggested to also evaluate them in other activities during the implementation of the forthcoming Physics blocks to appraise their progress in more detail.

V. CONCLUSIONS AND FUTURE WORK

The Tec21 educational model constitutes a disruptive model compared to the traditional lecture-based educational model. In this new model, the curriculum is based on the design of problematic scenarios or challenges, rather than on content, aimed to motivate students in order to obtain a more significant learning. While working with this Tec21 model, students are expected to develop disciplinary and transverse competencies in addition to learning contextualized concepts.

An important challenge of the Tec21 model is the appropriate evaluation of the competencies that students have to develop along their careers, given that these must be demonstrated through performance criteria showing the level of achievement reached by each student. In this work, we have attempted to measure disciplinary competences based on the reasoning level achieved by students in three categories, ordered in increasing thinking difficulty: *knowledge*, *application* and *argumentation*.

In this regard, a set of questions to address a Physics scenario about Kepler's Laws was designed according to the competencies established by our institution for the F1001B Physics block. The questions were grouped according to the categories previously mentioned, and were applied to a sample of $N = 319$ students from a total of 11 different sections taught by three different teachers.

Average grades for each question category were derived. Different average grades for the students of different teachers were obtained, probably due to their particular teaching style. Therefore, *t*-tests were applied to the complete sample in order to determine the existence of significant differences among the average grades of a given student in the three question categories. It was found that the average grade differences among the three question categories were statistically significant for the complete student sample, where the Knowledge category obtained the highest grades, followed by the Application category, and finally, the Argumentative category showed the lowest average grades. The average grades for the Knowledge and Application categories were above the passing course grade, but those for the Argumentative category were not. The average grade for the argumentative questions was found to be about 20% smaller than for the knowledge ones.

These results support the assertion that overall, students have more difficulties in acquiring higher order thinking competences, as it is expected. While they can often remember concepts and use them in simple questions, they have more difficulties when applying these concepts to solve a problem requiring the use of physical equations. Moreover, students often have troubles when facing questions that demand to extend or transfer the acquired knowledge and its application to new scenarios not previously foreseen. It is thus suggested to the professor to dedicate relatively more time to train students to develop high level reasoning skills in order to propose valid solutions to higher-order thinking argumentative questions.

This work can alert instructors to be aware of the required steps to promote adequate thinking and reasoning competencies for students, and therefore, to invite them to design appropriate scaffolding strategies suited to gradually accompany students in the development of higher-order competencies and reasoning skills throughout their majors.

As future work, the authors are planning to perform deeper analysis of the data, and to address other blocks of the first and second semesters, which last 5 weeks each, therefore permitting a stronger interaction with the students. This will allow a better outcomes comparison between traditional Physics courses and the new Tec21 Physics blocks. At the same time, we look forward to design appropriate strategies and methodologies to develop and evaluate the institutional declared competencies, in particular, those related to achieve higher thinking skills and tracking them along the student career.

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