

## Interdisciplinary block of learning challenges

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### Suggested Citation:

Damy, A. & Plascencia, M.G.L. (2020). Interdisciplinary block of learning challenges. *Contemporary Educational Researches Journal*. 10(1), 021–027. <https://doi.org/10.18844/cerj.v10i1.4611>

Received from July 15, 2019; revised from September 18, 2019; accepted from February 1, 2020.

Selection and peer-review under responsibility of Assoc. Prof. Dr. Deniz Ozcan, Ondokuz Mayıs University, Turkey.

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### Abstract

The Block of Sciences is a project that includes the contents of Differential and Integral Calculus and Mechanics around learning challenges that students solve along the semester. It becomes evident the development of not only disciplinary but also transversal competencies, so that students learn the contents and solve the challenges. In the concerning to the teaching work, there exist changes due to the fact that a very close communication among the team members during the full semester is necessary. The professor's role in a subject transforms into a learning facilitator or guide in order to create an appropriate environment to produce a better and more meaningful learning. In addition, there is a supervising professor for the challenges, who supports the students through all the process. With respect to the students, they have a key and active role, and as a consequence, they get a more significant learning.

**Keywords:** Competencies, educational innovation, multidisciplinary blocks, teamwork, Tec21.

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## 1. Introduction

The Block of Sciences project (Mathematics I, Mathematics II and Physics I) arises at the Tecnológico de Monterrey, Campus Guadalajara in Mexico, before the need of the subject of Physics I to rely on certain topics of Differential and Integral Calculus to explain some concepts and procedures. Some of these topics were not covered opportunely, but until the following semester, which meant that part of the work was done mechanically without a full understanding on the part of the students. Another of the trigger factors of this project was to strengthen the conceptual part of both disciplines and be able to achieve a more meaningful learning.

This project promotes the development of skills, is flexible in terms of the organisation of content and reinforces the relationship between concepts of Mathematics and Physics (multidisciplinarity), in a clearer and timely manner for students.

In the planning and realisation of this project, we took care to guarantee academic quality, for this, we worked with small groups and broadly experienced professors in the subjects. During the implementation, it was possible to deepen a little more in some subjects compared to what is worked in the ordinary or traditional courses and also solved a challenge associated with the disciplines.

The project began in the August–December 2017 semester with 15 students and in January-May 2018 with 11 students; both times there were two Mathematics professors, one Physics professor and one mentor, who was the one who worked more closely with the students in the elaboration of the projects that they had to present throughout the semester. Currently, we are working with two groups of blocks.

## 2. Literature review

The term ‘interdisciplinarity’ made its appearance in 1972, in the publication of the organisation for economic cooperation and development: ‘Problems of Teaching and Research in Universities’ (Apostel, cited by Miller, 2010). Interdisciplinarity arises in counterpart to the fragmentation of the knowledge in different disciplines. Already at that time, it was appreciated that when studying the contents separately, it was more complicated to reintegrate them to solve application problems. This is, especially, true at the university level, when students begin to solve problems in their area of professional interest, which usually occurs after their 2nd year. In addition, to reach a more comprehensive and detailed explanation of complex, real-life problems, several disciplines have to be combined and interact with each other, that is, an interdisciplinary approach is needed (De Greef, Post, Vink & Wenting, 2017).

Such are the benefits of interdisciplinary teaching and learning that at some universities interdisciplinary programs and projects have arisen. For instance, at the University of British Columbia, the UBC Mix Project is a program dedicated to advancing interdisciplinary education across the arts and sciences (Baloy, Fox & Sens, 2014; Costa, 2018; Kaplan Sayi & Kul, 2020; Kilic & Yildirim, 2020). In fact, UBC’s strategic plan Place and Promise is stated: ‘Through rigorous study within and across disciplines, students acquire the knowledge, inquiry and communication skills, professional abilities, and understanding of other cultures that enhance their personal development and enable them to contribute and lead in a global society,’ (UBC, 2012).

The purpose of education in the professional stage is to provide students with academic preparation according to the career they want to pursue and also that at the end, students are prepared to face situations that could arise in professional life. Because of today’s fast-paced changes, it is desirable that students have a clear idea of the type of situations they are going to solve and, above all, that during this process they develop the necessary skills, a way to approach these aspects and promote such abilities is interdisciplinarity (Llano et al., 2016), this has the consequence that students develop their ‘creative capacities, values and modes of action, which prepare them to face and solve the challenges in their future professional performance’ (Delfino & Mosqueda, 2008, p. 13).

As stated by Middendorf, cited by Gonzalez-Jimenez et al. (2014), the design of a course in which different disciplines are integrated must be done taking into account several aspects for both students and professors, including:

- Openness to different ways of thinking
- Appreciation and commitment to diversity
- Distrust of absolutes
- Ability to admit not knowing certain things
- Effective communication
- Flexibility
- Risk taking
- Recognise the need for conflicts
- Self-reflection
- Effective time management

In the specific case of the Basic Sciences, it is common that in the classes most of the time is dedicated to the procedural part and the applications are left out, as a result, they have an instrumental character since not enough emphasis is put on the conceptual part or the relevance that they have for the development of other disciplines (Alanis, 1996). For example, in most university majors, Mathematics is not an end but a means to study other disciplines, such as Physics. Paradoxically, 'there are students who having accredited a traditional Calculus course are not able to recognise what they studied there, in their areas of interest' (Alanis, 1996, p. 140), that is, students do not always develop the ability to extrapolate the knowledge of the basic sciences to other disciplines.

On the other hand, unlike a few years ago, it is currently very common for work teams to be multidisciplinary, even with areas of knowledge that apparently would not have similar interests. If we think about this situation, nowadays, the way to prepare future professionals in universities should consist not only in providing them with academic preparation of their area but also in giving them a global vision and promoting interdisciplinary work, so that even as students begin to know how his life could be in the workplace, in addition, the learning experience arises not only from the disciplinary area, but also from the interaction between group participants as stated by Gonzalez-Jimenez et al. (2014). Leon and Valdes (2009) comment that interdisciplinarity is an aspect that today is very relevant in the work of many professionals, since it is an issue that is imposed in any scientific and technological process of the historical moment that we live, professors must be involved.

The Tecnológico de Monterrey has decided to evolve towards a new educational model that allows its students to become leaders prepared to face the challenges and opportunities of the 21st century. This model, known as Tec21, bases its success on improving competitiveness by enhancing skills and developing the required competencies in different professional fields. (<https://observatory.itesm.mx/tec21>, consulted on 11/14/2018).

The TEC21 Educational Model aims to provide comprehensive training and improve the competitiveness of students in their professional field by enhancing the skills of future generations to develop the required competencies that allow them to become leaders who face the challenges and opportunities of the 21st century. (<https://observatory.itesm.mx/tec21>).

The Block of Sciences is an alternative to foster a learning environment that responds to the needs stated by the students exit profile. Particularly, in higher education, it is necessary to ensure that they have the competences that correspond to their profession, as well as to promote transversal competences, such as collaborative work and other skills, such as the self-learning ability. In fact, such is the importance of the development of competences, nowadays, that in a vote among the professors of the Tecnológico de Monterrey, Competency-Based Education was the most relevant one (Edu Trends, 2015).

Specifically, in the Block of Sciences, it was decided to promote the following competences based on the engineering student's graduate profile:

1. Proposes solutions in scenarios that show problems related to objects in movement and / or rotation.
2. Analyses the behaviour of one magnitude, as well as the variation with another, in real situations, with differential calculation tools and representing mathematically the relation between the magnitudes.
3. Analyses real situations that highlight the application of physics and mathematics in the kinematics and linear and angular dynamics, using a vector language.
4. Gives a solution to practical situations of physics that involve differentials, definite and indefinite integrals through the corresponding techniques.
5. Work collaboratively in interdisciplinary teams to solve problems, ensuring participation and learning from their peers.

A resource to promote competencies is the use of challenges, which according to what is stated in the Tec21 Educational Model, is defined as 'a living experience designed to expose the student to a challenging situation in the environment to achieve specific learning objectives. Challenges contribute to the development of disciplinary and transversal competences of the students, since in them they apply, individually and collaboratively, their knowledge, skills, attitudes and values.'

### 3. Methodology

Given the focus of the new educational model TEC 21, where interdisciplinarity plays a fundamental role and taking into account that they were first semester students, it was proposed to make a block of Sciences, which would include three subjects.

As mentioned above, it was proposed to include Mathematics I (Differential Calculus), Mathematics II (Integral Calculus) and Physics I (Mechanics) in the block, since Physics requires the conceptual part of both courses to be identified as an area of opportunity.

The teaching team consisted of four professors, two of Mathematics, one of Physics and one teacher mentor for the challenge. The two Mathematics professors indistinctly taught Mathematics I and Mathematics II subjects, this measure was taken to standardise levels of difficulty and evaluation criteria and also to achieve in the students the learning of the topics with the same depth and in a significant way, independently who the professor was. For being the first time it was implemented, it was necessary that broadly experienced professors taught these courses. In the same way, the Physics professor was chosen and, in the case of the mentor for the challenges, a Mechatronics Engineer with a great capacity for project design.

In the August–December 2017 semester, we worked with two challenges. The objective of the first challenge was to work with the theme of 'parabolic shooting' and the issues underlying it. The second challenge was related to the development of a roller coaster, which included the topics of kinematics for the course and the latter was delivered at the end of the semester.

or the January–May 2018 semester, it was decided to work with a single challenge, which was solved throughout the semester, which consisted of a roller coaster, but this time, more parts were included, and therefore more topics, such as parabolic shot, rotational, collisions, work, energy and power, with the intention of promoting more analysis by students. Throughout the two semesters, weekly meetings were held with all the professors involved, where the schedule of the topics was discussed and adjusted, the progress of the projects was reviewed and general comments were made on any situation or unforeseen event that had arisen to timely solve it. We considered necessary to have the planning at least 3 weeks in advance. Each time a module was finished, an exam related to it was applied. It is important to notice that there were exclusive modules of Mathematics, other exclusive of Physics and others that included both disciplines. The idea was that at the end of the

module although progress was being made, the students were given a little time (2 or 3 days) so that they had the opportunity to complete the tasks and activities of the module and could clarify the doubts with the professors, so they were well prepared for the exam.

When the time and dynamics of the class allowed it, work was carried out with activities in the classroom, some individual and others in teams, at all times the purpose was to achieve a more meaningful learning of the topics. If the degree of difficulty of the topics to be covered was a bit high, teams were worked on, for the simplest activities they worked individually. Additionally, there were assignments, both from the textbook and others designed by the professors themselves, and in particular, in the semester of January–May 2017, work began on a technological platform.

The evaluation was continuous throughout the semester and for both blocks, included activities in class, quizzes, homework, module exams, the delivery of the progress of the projects and a final exam for each of the subjects. We also had immersion weeks, these consist of a 100% dedicated work to the challenge with the support of the teacher mentor and the other professors. In both semesters, the evaluation of competences was considered, for which interviews with the students were carried out and checklists were applied.

#### 4. Results

Unlike the courses that are carried out in a traditional way, in the Block of Sciences, it was possible to review in a more exhaustive way some topics, such as the particular case of derivative applications (optimisation problems).

In the case of Physics, a more meaningful learning was promoted since the required mathematical concepts were covered at the moment they needed to base the concepts of Physics and not to see them in a purely theoretical way as a mere definition.

As mentioned above, in both semesters the groups of students were small, this allowed that the work with the students was given in a closer and coordinated way, with a more personalised attention than could be given in the traditional groups with around 30 students. At this stage, this was important because it allowed the opportunity areas of this project to be detected and taken into account to make the replicas with the groups that we usually have on the Campus.

The grades assignment in the Block was the same as in the traditional groups, that is, it was necessary to give a numerical score between 1 and 100 for each of the three subjects.

As shown in Table 1, which includes statistical data of the subject groups related to the Block, in the three subjects, the average obtained in the Block and the percentage of approved students were greater than in the traditional groups and in the concerning to the standard deviation, it was smaller in the Block.

**Table 1. Results comparison between the traditional groups and the Block**

	Physics I		Mathematics I		Mathematics II	
	Traditional group	Block	Traditional group	Block	Traditional group	Block
Average	82.0	87.6	76.1	85.6	69.8	85.6
Standard deviation	12.5	8.7	15.9	9.8	15.9	9.8
Percentage of approved students	82.2	100.0	76.3	93.3	66.4	93.3

In the traditional groups, there were also groups attended by the same teachers of the Block, that is, in some cases there was no change of variable in terms of the professor. The groups' sizes in the three subjects were greater except in one of Physics I; there were some groups with a number of students close to the Block's, when comparing with the small groups also the statistics of the Block show a better performance.

The variables that were present in the Block and not in the other groups, are the work in the challenge, the accompaniment of a tutor for the challenge and a greater emphasis in the development of the competences. We consider that above all, seeing and working in the application of concepts of Physics and Mathematics is what made students learning more meaningful and what resulted in a greater motivation and commitment to the subjects and work that should be done.

In addition to the academic aspect, the development of skills and competencies necessary for teamwork was also favoured, such as responsibility, good communication among the members of the team and the organisation to work on the achievement of a project.

In the concerning to the professors, throughout this process the weekly meetings allowed to keep a control about what happened in the group, both in the academic and attitudinal aspect and the way of responding to the sessions and amount of work of the modules and the development of the challenges. One of the benefits of these meetings was the possibility of adjusting the issues in quantity and depth according to what was required. This part of flexibility in the organisation of the contents of the course was essential to optimise the time and to have a positive impact on the students' learning. The good communication among the team of professors is an essential element in a project of this nature, especially because it is a team and a multidisciplinary work. The fact of working with a challenge creates the need to consciously design assessment instruments, such as rubrics, observation guides or checklists that allow estimating different aspects of students' work, such as the development of competences. The challenge was an instrument that allowed the alignment to the Model TEC21 to be done almost automatically, it made evident the development of disciplinary and transversal competences that the students could develop and that without them, it would have been very difficult to achieve it only through the study of the contents related to the topics that they applied to achieve the challenge.

## 5. Conclusions

The change of model was not so natural for all students, because most of them already had a scheme of how to learn Calculus and Physics from previous experience in high school. The attitude and good disposition of the students are important for the implementation of projects of this type to work and succeed. The communication among professors facilitated the following aspects: search of strategies and activities that favored the learning, to know better the students and to detect their academic needs, to standardise the levels of difficulty in the contents and exercises.

The degree of difficulty of the challenge must be determined in such a way that it involves contents according to the syllabus, favours the visualisation and analysis of concepts considering that they are first semester students and that the challenge is intended to correspond to a problem of general interest for engineering students, given that the motivation plays a key role in carrying out a job that will be carried out throughout the semester. The area of opportunity is to improve the design of assessment instruments focused on competencies, which are fundamental in the Tec 21 Educational Model.

## Acknowledgements

'The authors would like to acknowledge the financial and technical support of Writing Lab, Teclabs, Tecnológico de Monterrey, Mexico, in the production of this work.'

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