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Application of Learning Analytics to Improve Higher Education

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Abstract

In the digital era, the teacher assumes very diverse roles among which are to be an adviser, a generator of multimedia content, and more recently a data analyst. Big data analytics may play a major role in Higher Education for all the agents involved, the teachers and educators, the students themselves and the managers or heads of university centers. This paper applies learning analytics to the subject of Theory of Machines and Strength of Materials of the bachelor's degree in Chemical Engineering at Universitat Politècnica de València (Spain). The aim of analyzing the available information is to improve teachers' actions and communication, to enhance resource efficiency, to assess classroom procedures, the achievement of transversal competences, the student typology and their results, or the attitudes and commitment they acquire with the subject taught. Results show the existence of niches with competitive advantages, improvements in the quality and performance of the teaching-learning experience.

Keywords: Learning analytics; Big data; Transversal competences; Information and Communications Technology, e-Learning, Blended learning

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1. Introduction

Learning analytics is an emerging research field that is growing in a significant way. They involve the measurement, collection, analysis, and reporting of data on the students and their contexts, in order to understand and optimize learning and environments in which they take place. The remarkable emergence of this field is attributed to several factors (e.g., Dollár and Steif, 2012; Ferguson, 2012):

- Big data: the generalization of institutional databases and Virtual Learning Environments (VLE) involves the management of large data sets by institutions educational institutions, with the aim of using them to improve teaching-learning process.
- Online learning: the increasing presence of Big data in education is accompanied by an increase in online and blended teaching-learning environment (BTLE), as well the widespread use of Open Educational Resources (REA). They are any type of educational material that is in the public domain. They cover textbooks, lecture notes, syllabi, assignments, tests, videos, screencasts, and Massive Open Online Course (MOOCs). They are published under open licenses, such as Creative Commons (CC), that stipulates how materials may be used, reused, shared, adapted, and modified in agreement with specific needs.
- The worldwide exponential development of Information and Communication Technology (ICT) over the past decade.
- National interests: countries and international organizations are showing a greater interest in measuring, demonstrating, and improving educational outcomes and optimizing learning for the benefit of society.

2. Material and Methods

The European Higher Education Area (EHEA) reoriented the focus attention of educational system towards the implementation of student-centered learning, facilitating that they are active, autonomous, critical, and reflective. There are multiple learning environments established that coexist with total naturalness, with the ultimate goal that students necessarily acquire the specific knowledge of their degree and develop a corpus of competence required in the professional environment (OEI, 2019).

The main objective of learning analytics is to understand and improve learning and the environments in which it occurs. However, learning is a complex process in which multiple factors intervene. For this reason, it is necessary to use tools, techniques, and methods from various fields of research to study it.

The collection of data from the students, when they are in a learning context, opens the door to new interpretations about what happens during the execution of the learning processes.

It is possible to establish a classification of the uses of data in Learning Analytics, for example, referring to the prediction of student performance, providing feedback for instructors, grouping of students by learning profiles, detecting atypical behaviors or differentiated rhythms, analysis of uses in social networks, analysis of the development of competencies, planning and scheduling of courses, etc., so that the field of empirical research it is paid for future generations of teachers.

The potential benefits of learning analytics are analyzed through a case study. Specifically, it is applied to the subject of Theory of Machines and Strength of Materials (TM&SM), which belongs to the third year of the bachelor's degree of Chemical Engineering. It was taught in the first semester of previous academic year at Universitat Politècnica de València (UPV, Spain).

It is a compulsory subject that consists of 6 ECTS (European Credit Transfer and Accumulation System), three of which are theory lessons and the other three are practical classes. The subject was taught under a blended learning (BL) methodology because of the coronavirus pandemic. A blended learning environment entails in-person classes, which are complemented with online learning. In addition, resources like videos, articles, screencasts, podcasts, and more are meant to enhance in-person classes and create an enriched learning experience. The classes were broadcasted live through the communication platform Microsoft Teams®, thus allowing the student to choose between attending the classes in-person in the university classroom, or by Teams completely online. In addition, since the classes were recorded students could also consult them asynchronously, which is undoubtedly a great advantage for students.

It is made up of two differentiated parts taught by two departments, with a weight of 50% on the final grade for each part. The Department of Continuous Medium Mechanics and Theory of Structures teaches the first part, which is related to the Strength of Materials, while the Department of Mechanical and Materials Engineering, to which I belong, teaches the second part related to Theory of Machines.

In the 2020-2021 academic year there were only one group with seventy-seven students enrolled. Classroom theory is taught by two professors, each one from a different department. Additionally, there are four groups of practical lessons, which are taught by four teachers. Two groups are taught by the theory lessons teachers, while two additional teachers are needed for the other two groups.

This subject, which belongs to the common block to the industrial branch, is related to other subjects of the syllabus degree of Chemical Engineering, such as Industrial Equipment Design or Construction and Industrial Architecture.

The syllabus regarding to the two different parts of the subject is subsequently presented:

- Strength of Materials: the purpose of this part of the course is to introduce the student to the study of mechanics of deformable solids. At the end of the course, students will be able to identify and calculate the internal forces that occur in the solid because of the application of external forces, calculate the stresses in elementary structural systems of bars (beams and gantries) and properly dimension structural elements subjected to static loads.
- Theory of Machines and Mechanisms: it is a basic discipline in all engineering degrees of the industrial branch and occupies a fundamental place in very diverse fields of application. This subject is intended to provide a first introduction to the analysis and design of machines. To perform their function, machines transform movements and actions through mechanisms to adjust them to the useful work to be done. Starting from the concepts of rigid solid dynamics, studied in physics, these are applied to the kinematic analysis (relation between entry and exit movements) and dynamic (relation between applied actions and resulting movements) of mechanisms. The syllabus covers the basic concepts of the theory of machines and mechanisms, the kinematic analysis

of plane mechanisms, the dynamic problem (including the Newton's Laws and the Principle of Virtual Powers), and the design of anti-vibration systems. There are three practical classes, in which students must solve kinematic and dynamic problems using a specific software and to design an anti-vibration system.

This research also aims to evaluate the transversal competences (TC) as defined by the UPV. They try to synthesize a competency profile for its students, assuring a reference framework of all degrees. They encompass a set of cognitive skills and metacognitive and instrumental and attitudinal knowledge of significant value for the knowledge society. They are related to a set of attitudes and procedures that can be translated from one specific professional field to another. Moreover, they are crucial and transferable in relation to a wide variety of personal, social, academic, and work contexts throughout of the life. UPV defines thirteen transversal competences (UPV, 2020).

In this subject three transversal competences (TC) are evaluated:

- TC-03. Analysis and problem solving. Analyze and solve problems effectively, identifying and defining the significant elements that constitute them.
- TC-04. Innovation, creativity, and entrepreneurship. Innovate to respond satisfactorily and in an original way to personal, organizational, and social needs and demands with an entrepreneurial attitude.
- TC-05. Design and project. Design, direct and evaluate an idea effectively until it is concretized in a project.

The Theory of Machines and Mechanisms part of the subject is taught by professors Llopis-Albert and Rubio, which have an extensive experience in this field. To be able to transmit knowledge effectively, especially in the last years of the degree, it is important that teachers keep up to date with technological advances in the subject. They have published many articles closely related with the subject in the last five years. For instance, Llopis-Albert et al., 2015-2021; Rubio et al., 2015-2021; Valero et al., 2015-2021.

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3. Results and discussion

Learning analytics and statistics are applied to enhance the teaching-learning process. On the one hand, Figure 1 presents the online resources visits to the subject site, which belongs to the UPV institutional platform (www.upv.es). On the other hand, Figure 2 depicts the online resources visits made by each student to the subject site. It shows the most active user, i.e., the user who has consulted more resources. A total of 12470 visits from the seventy-seven students enrolled in the subject to the platform were received for the whole term. The average length of stay per visit is 31 minutes. The average time Statistics show that there is a high correlation between the student activity and their score. The site is only available to members of the course and includes all the learning materials: announcements and organizational tasks, syllabus, schedule, teaching guide, audio-visual materials generated over the classes (both recorded videos of the classes and annotations on the virtual whiteboard), screencasts, and PDFs with the theory, practical lessons material, solved exams from past years, solved. It is observed that the greatest number of visits occurs in the weeks when each of the two partial exams are performed.

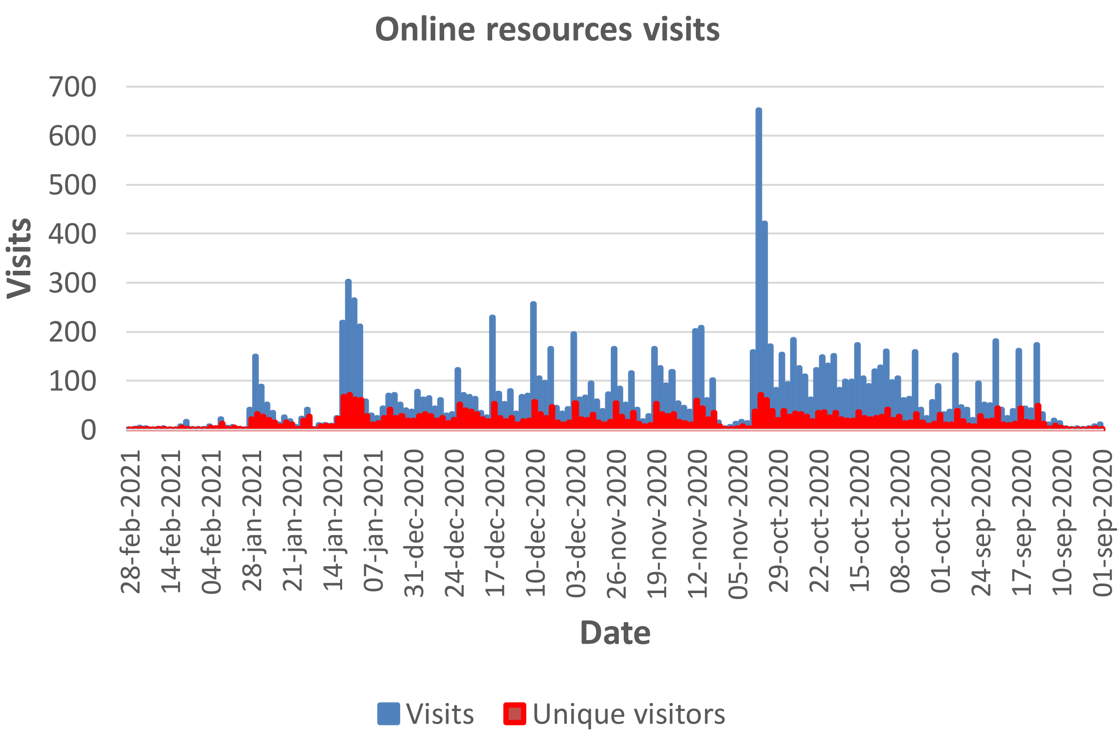

Figure 1. Online resources visits to the subject site, which belongs to the UPV institutional platform.

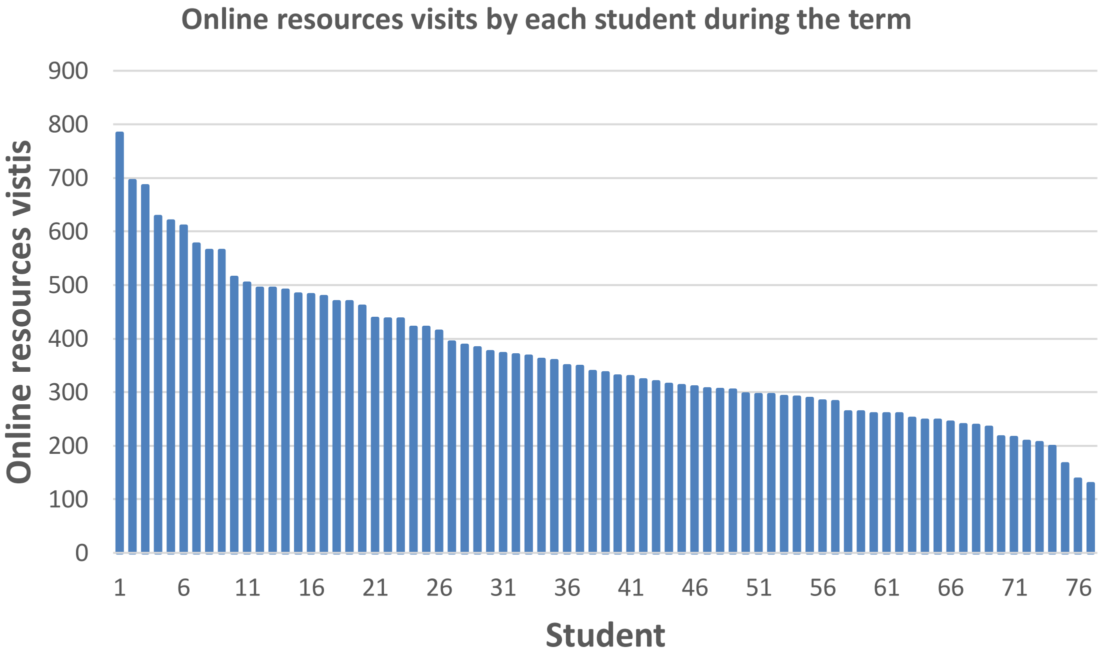

Figure 2. Online resources visits by each student during the term.

Table 1. Final grades of the subject Theory of Machines and Strength of Materials.

GRADES	Alumni	Exam attendance	Total
Distinction (Merit with distinction)	2	2.60%	2.60%
Merit (9 to 10)	10	12.99%	12.99%
Good (7 to 8.9)	31	40.26%	40.26%
Pass (5 to 6.9)	27	35.06%	35.06%
Fail (<5)	7	9.09%	9.09%
Exam attendance	77		100.00%
No attendance	0		0.00%
Average score	Standart deviation	Maximum score	Minimum score
7.03	1.9	9.9	0.60

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Table 1 and Figure 3 present the final grades of the subject Theory of Machines and Strength of Materials (TM&SM) and also the final grades for the practices of the part of Theory of Machines ™, while Table 2 shows the final grades of the practical classes of the part of TM. Table 2 illustrates the final grades of the practical classes of the part of Theory of (TM). A wide dispersion of scores has been observed in the scores, which is highly correlated with the different time devoted to the subject as presented in Figure 2.

Results show a high academic performance, in which only 5 students failed the subject out of 77 (Table 1). It is notable that all the students enrolled in the subject attended the exam. The average score is remarkable and most of them achieved a score between 7 and 9 (40.26% of the students for the subject and 65.06% for the TM practices). However, a higher average score is achieved in the practices. This is because they are easier an received the help of the teachers. Moreover, only one student failed the practices lessons and there were 12 students that obtained a score between 9 and 10 (Table 2). The standard deviation of the scores is slightly higher for the practices (2.35 if compared to the 1.9 of the score of the subject).

Table 2. Final grades of the practical classes of the part of Theory of (TM).

TM PRACTICES GRADES	Alumni	Exam attendance	Total
Merit (9 to 10)	12	15.58%	14.46%
Good (7 to 8.9)	54	70.13%	65.06%
Pass (5 to 6.9)	10	12.99%	12.05%
Fail (<5)	1	1.30%	1.20%
Exam attendance	77		92.77%
No attendance	6		7.23%
Average score	Standart deviation	Maximum score	Minimum score
7.5	2.35	10	3.09

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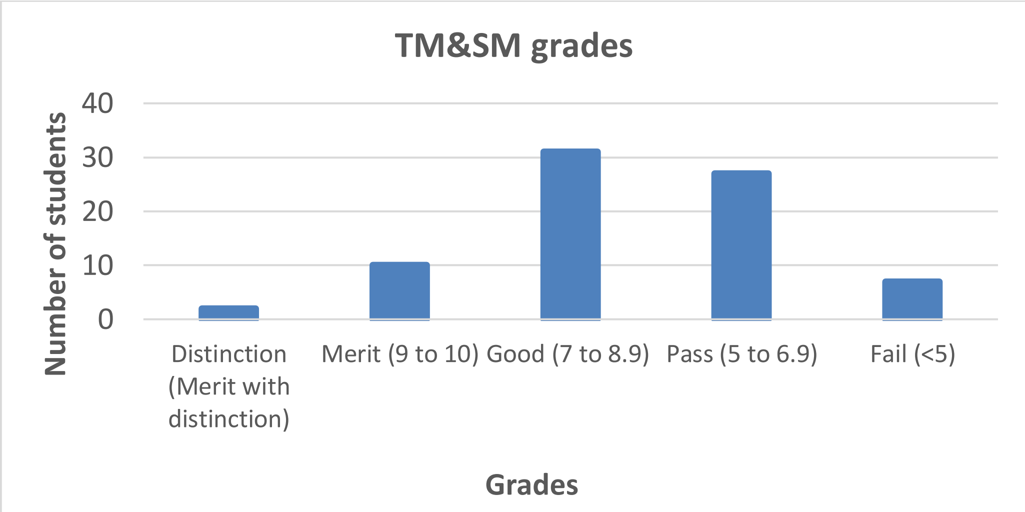

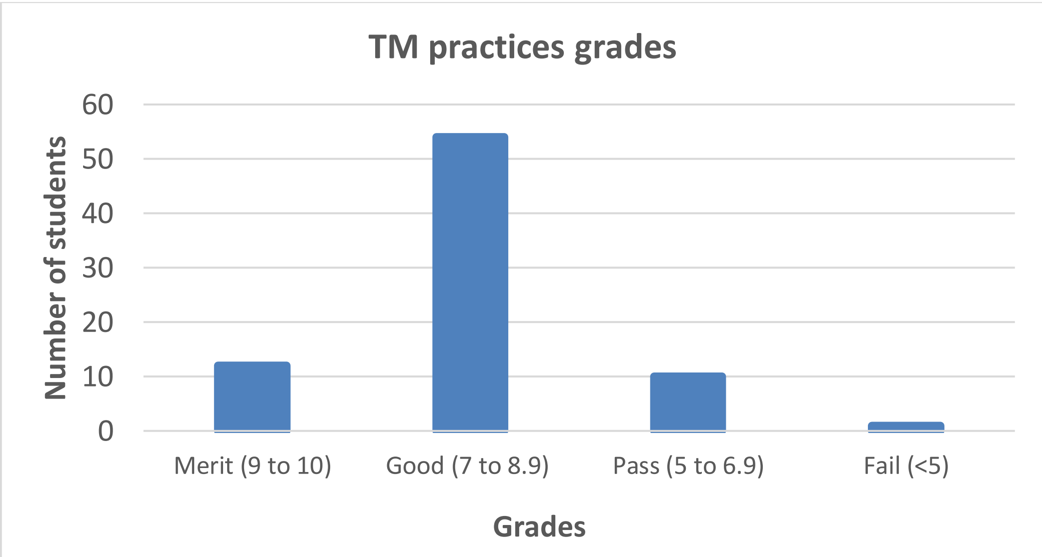

Figure 3. Final grades of the subject Theory of Machines and Strength of Materials (up) and final grades for the practices of the part of TM (down).

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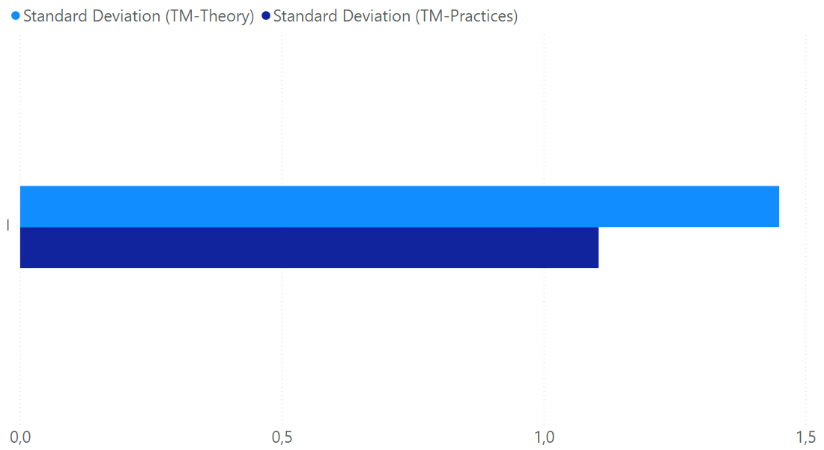

Figure 4. Standard deviation of the marks of the Theory of Machines (TM) subject regarding theoretical lessons (TM-Theory) and practical lessons (TM-Practices).

Figure 4 displays the standard deviation of the marks of the Theory of Machines (TM) subject regarding theoretical lessons (TM-Theory) and practical lessons (TM-Practices). Since the exam of the theory part is more difficult, its standard deviation is higher.

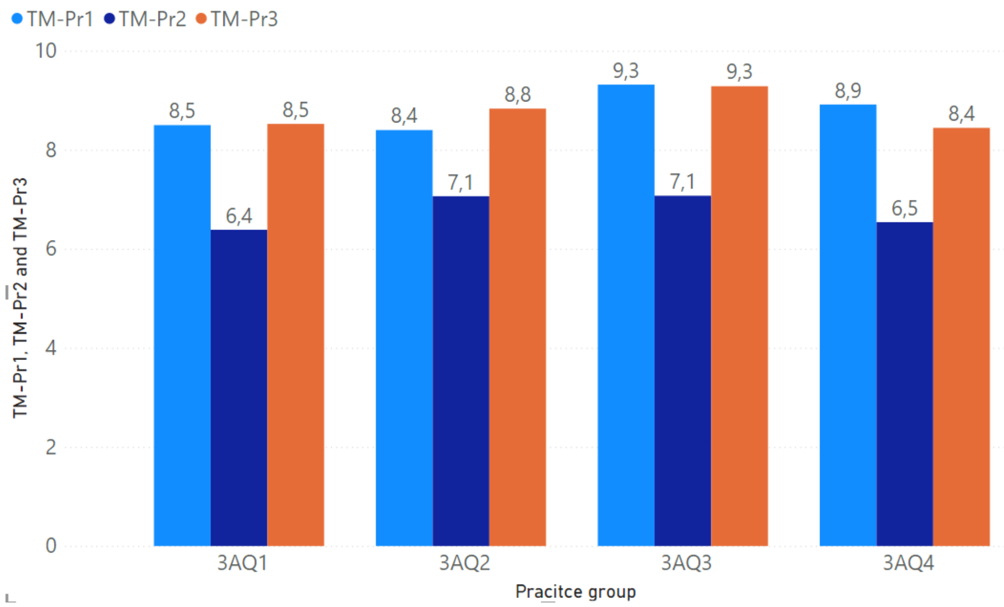

Figure 5. Theory of Machines (TM) grades with regard to the three practical lessons (Pr_i) and four existing groups (3AQ_i).

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Figure 5 shows the marks of the 3 practices of the part of Theory of Machines (TM) for the four existing groups (3AQ_i). It is observed that the second practice is the one with the lowest notes because it is the most complex.

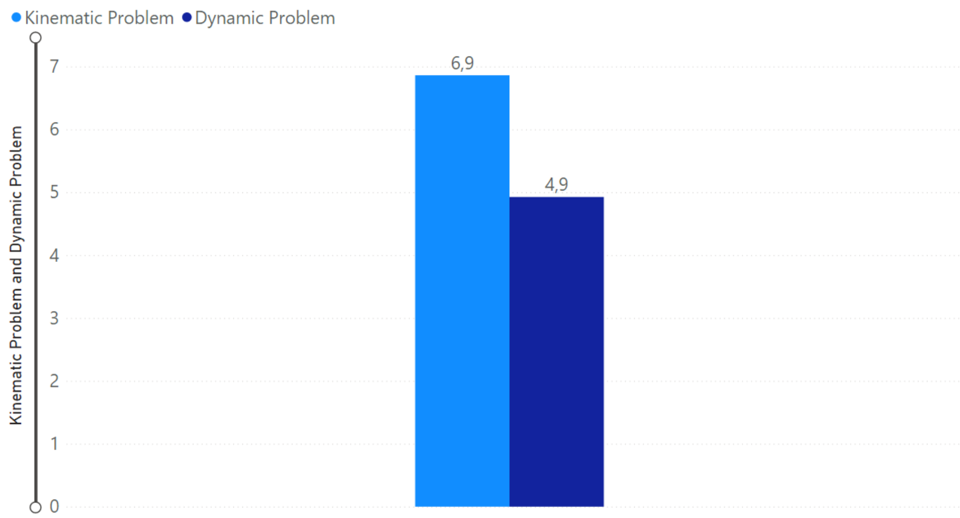

Figure 6. Theory of Machines (TM) grades regarding the kinematic and dynamic part of the subject.

Figure 6 shows the Theory of Machines (TM) grades regarding the kinematic and dynamic part of the subject. It is observed that the average score of the dynamics problem is quite low and should be corrected. However, the explanation for this may be due to the fact that it is taught at the end of the term and students have less time to prepare it.

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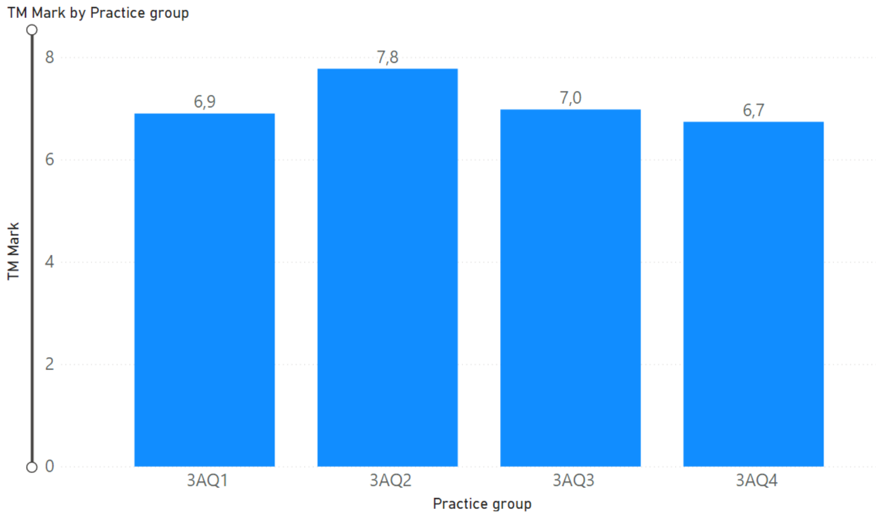

Figure 7. Theory of Machines (TM) grades regarding the four existing practice groups (3AQ_i).

Figure 7 depicts the Theory of Machines (TM) grades regarding the four existing practice groups (3AQ_i). It is clear that students belonging to the 4 groups obtain similar marks, although the 3AQ2 group stands out from the rest.

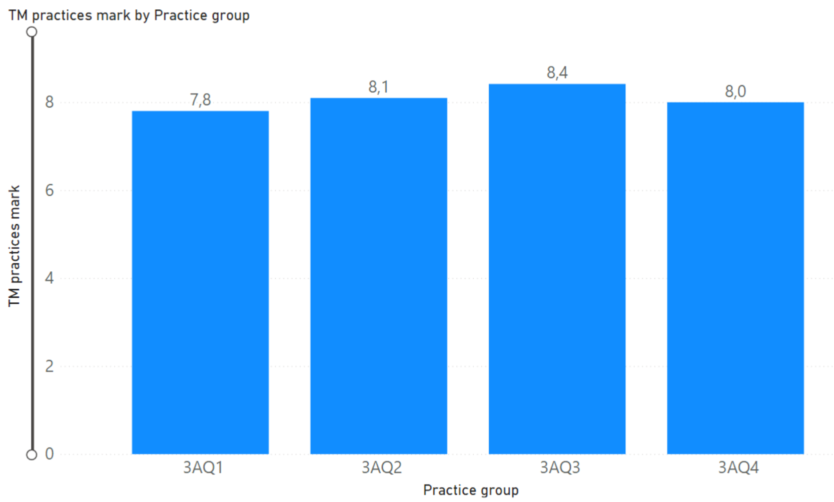

Figure 8. Final mark of practices of the part of Theory of Machines (TM) for the four existing practice groups (3AQ_i).

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Figure 8 presents the final mark of practices of the part of Theory of Machines (TM) for the four existing practice groups (3AQ_i), which allows to determine discrepancies between them. It is observed that the students belonging to the 3AQ1 group are the ones with the worst results. The teacher responsible of such group should detect what was the problem to correct it.

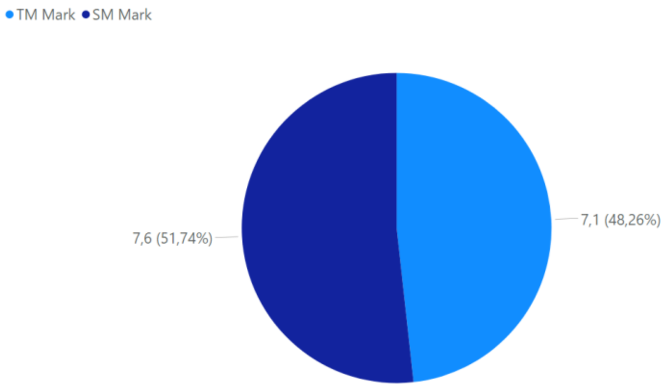

Figure 9. Grades for the two parts of the subject, Theory of Machines (TM) and Strength of Materials (SM).

Figure 9 presents the grades for the two parts of the subject, Theory of Machines (TM) and Strength of Materials (SM). Students obtain higher marks in the part of Strength of Materials, but the difference is reasonable.

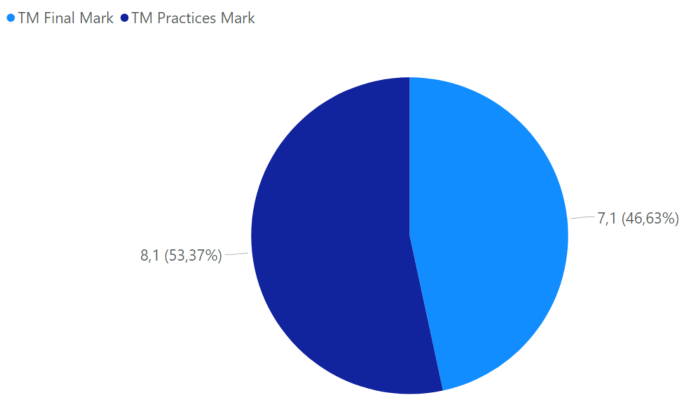

Figure 10. Theory of Machines (TM) final grades regarding the theory and practical evaluation.

Figure 10 presents the Theory of Machines (TM) final grades regarding the theory and practical evaluation. Students obtain higher marks in practices in comparison with the rest of the evaluation acts (open-response exams), since they are easier and receive help from teachers during the lab sessions.

In view of the experience gained and the results, most of the learning-teaching process is satisfactory, but there is a room for improvement:

- The academic performance of the students has been satisfactory with only 9% failures.
- The discrepancy in the scores of the TM and SM parts should be corrected.
- The practice scores are very high and more or less equal between the different groups.
- Students get lower marks in the dynamics part, perhaps because it is taught at the end of the term and students have less time to prepare it.
- The practice marks are significantly higher than those of the theory exam.
- The dispersion in the marks of the theory and problems exam is greater.
- It is worth mentioning that the attendance to classes in-person was around 45% of the students, while the rest of students attended the classes through Teams. Only a couple of students did not attend the classes neither in-person at university classroom or by Teams. Eventually, these students failed the course. As an improvement for next academic courses, these students should be contacted before the end of the course to correct this situation.
- Attendance to practices either in-person or online was 100% of the students and the average grade was high (around 7 points) and only 3 failed.
- It has been observed that the students who are more active in the site platform are the ones with the best grades. Thus, a great correlation is observed between academic performance and devoted effort.
- It is estimated that the time spent to obtain the average grade for the subject is adequate (7.03 points) and only 9% fail.
- It is appreciated that the resource with the most accesses in the part of Theory of Machines is the one that presents a summary of the subject with the basic equations. This leads to the belief that students prefer material with the fundamental ideas and concepts of the subject than much material that takes a long time to study.

- The possibility of including other materials, such as learning games, could be investigated.
- The largest number of visits is made on dates immediately prior to the partial exams. The student should be made aware of the importance of continuous work.
- From the dashboard data, it has detected that there is a group of practices with significantly lower marks than the other three. Thus, there should be better coordination between the different practice teachers to correct this aspect.
- The practices have been carried out by means of an online exams tool embedded in the site platform. It has been observed that the grades have been very high, even though students were connected online and had to work more autonomously.
- It is observed that the average score of the dynamics problem is quite low in comparison with the kinematic problem and it should be corrected.
- It is observed that the second practical lesson of the TM part is the one with the lowest score because it is the most complex. The level of difficulty of the practices should be equalized.
- With regard to qualitative data, based on the students' comments, they were satisfied with the development of the subject, the available material, etc. They suggested that the basic equations should be available during the exam.
- It is observed that the students obtain higher marks in the part of Strength of Materials (SM). This could be corrected with greater coordination between the teachers of the Department of Mechanical and Materials Engineering and the Department of Continuous Medium Mechanics and Theory of Structures in order to equalize the level of evaluation acts.
- It is observed that students obtain higher marks in practices with respect to the rest of the evaluation acts (open-response exams). The level of difficulty of the practices could be increased by making students work more autonomously and without so much help.
- It is considered correct that the students belonging to the four practice groups obtain similar marks.

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4. Conclusions

The sudden outbreak of the coronavirus pandemic forced a quick adaptation of the traditional in-person educational model to blended or hybrid models by means of ICT tools. This paper applies learning analytics and statistics with the aim of improving the quality and performance of the teaching-learning experience. Results have shown the existence of niches for improving the students' performance. The detected gaps are intended to be solved in the following academic year. The proposed blended model has been proven to be suitable for the achievement of the transversal competences, and to improve both the students' performance in a mechanical engineering subject, and their level of satisfaction. In fact, the student's satisfaction survey regarding the subject, evaluation activities and teachers are very positive. Results have shown an excellent pass rate and a high correlation among the evaluation of the open response written answers, the objective tests, the practices, and the final grade for the subject.

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