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Improving Students' Engagement and Performance Through New e-Learning Tools in Laboratory Subjects in Mechanical Engineering*

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In this paper we present the design, development, implementation and evaluation of a new assessment methodology for the subject *Laboratory of Elasticity and Strength of Materials* of the degree in Mechanical Engineering in order to improve learning outcomes while simultaneously engaging students in their learning process. This set of different assessment methods is based on e-learning tools in combination with traditional face-to-face practical training, and carefully balances **formative assessments** (to improve instruction and student learning) and **summative assessments** (to evaluate individual academic achievement) within a well-designed time-distributed program. The results of an anonymous student satisfaction survey show that these improvements have been very well received. 73% of the students polled are very satisfied with the quality and usefulness of the method and 86% of the students think that the assessment feedback is sufficiently detailed to enable them to identify their own particular weaknesses. Regarding the fairness of the grading process, more than 60% of the students polled considered two of the four assessment methods to be extremely fair. The results from academic outputs show a significant improvement after this methodology is applied. Comparing the grades obtained in the last five academic years we can conclude that the dropout rate has been reduced from 41% in 2011/12 to 18% in 2015/16 as has the number of failed students (from 20% to 11%). Regarding the number of students achieving good grades (above 7/10), it has increased noticeably from 3% in 2011/12 to 26% in 2015/16. Correlating the students' final grades with the individual grade of each e-tool, we can conclude that self-assessment tasks before laboratory sessions are a great assistance in understanding what we consider essential for the successful completion of each session and self-assessment tasks after laboratory sessions are a good guidance for students to know which their level of knowledge before the exams is. It also confirms that students with higher marks on self-assessment tasks are also the ones with higher marks on the exams, which indicates that self-assessment tasks are useful to prepare the partial test exam as well as the final oral exam. We can conclude that this comprehensive assessment program contributes to improving academic outcomes, ensuring that students acquire the adaptive and autonomous learning characteristics necessary for enhanced engagement with the learning process and a subsequent successful performance.

Keywords: formative assessment; summative assessment; learning outcomes; student satisfaction; student engagement

1. Introduction

Research has demonstrated that engaging students in the learning process increases their attention and focus, motivates them to practice higher-level critical thinking skills and promotes meaningful learning experiences. Instructors who adopt a student-centered approach to instruction increase the opportunities for student engagement, which then helps everyone to be more successful in achieving the course's learning objectives [1–4]. On the basis of these principles and since the incorporation of Spanish universities into the European higher education system, teaching methodologies have been radically overhauled, creating a more open and more student-centered educational experience that fosters self-directed, participatory, active, group-oriented and engaged learning. Consequently, lecturers have sought to find new methodologies and learning tools that strengthen the students' role, enabling them to take control of their own learning processes. Some excellent examples in Spanish universities can be found in the work done by Díaz-Lantada and co-workers [5], Pérez-Benedito and co-workers [6], Jiménez and co-workers [7] and Montero and co-workers [8]. All these new methodologies implemented are geared towards fostering student participation in order to promote an autonomous learning process in a student-centered environment. One of the methodologies that has been demonstrated to be very effective is the integration of practical training into the university curriculum to enable students to develop an appropriate professional profile.

Following this reasoning, the degree in Mechanical Engineering (DEM) at the Universitat Rovira i Virgili uses unique teaching methods that bolster the students' aptitudes and abilities by applying advanced experimental and practical teaching techniques. Experimental techniques are used for a number of practical (laboratory) subjects that dovetail with the corresponding theoretical subjects but

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have their own assessment, management and organizational structures.

The laboratory subject analyzed in this paper is the **Laboratory of Elasticity and Strength of Materials**, which is taught in the second semester of the second year of the DEM. Students complete 60 face-to-face teaching hours in one semester and acquire a practical understanding of the main concepts of the strength of materials as applied to engineering systems. The basic contents are divided into three modules:

- **Module I:** characterization, testing and inspection of structural materials (four practical sessions (PS1-4)).
- **Module II:** experimental characterization of strain gauge measurement techniques (four practical sessions (PS5-8)).
- **Module III:** analysis and application of the finite element method (four computer sessions (PS9-12)).

Each week students attend a 4-hour practical session for one of the modules. Each module has a coordinator who is responsible for the theoretical content, the teaching material, the assessment system and coordination with the other lecturers that teach the subject.

The main learning outcomes of this subject are, broadly speaking, the ability to experimentally apply the fundamentals of elasticity and strength of materials (deriving from a specific competence), the ability to put engineering knowledge into practice (deriving from a transversal competence) and the ability to produce correct oral communication (structured, clear and appropriate to the communicative situation) (deriving from a core competence). **The assessment system** for this subject focuses on both the content and the acquisition of these competences (see Table 1).

From our experience of teaching this subject, we detected certain problems that impeded or delayed the acquisition of the learning outcomes while significantly reducing the success rate and increasing the dropout rate. A systematic decline in student satisfaction was also detected each academic year. In order to reverse the trend, in the academic year 2013–14 we made drastic changes to the teaching and learning methodology, turning it into a more interactive system by introducing a blended-learning strategy based on the use of different teaching tools that combine face-to-face methods with e-learning technologies. The enhanced teaching environment included upgraded teaching materials, new self-assessment methods and video clips providing detailed instructions for each practical session (PS). These changes were also aimed at improving autonomous learning before and after each PS. All this new learning methodology was presented in detail in [9] and was very well received. Measuring the degree of student satisfaction, ascertained through an anonymous survey, 98% of the students considered that video clips were very useful for better understanding the subject and 100% of them thought that the new self-assessment methods helped them in reducing time for preparing the oral exam. Regarding the upgraded teaching material, the students rated these materials with a mean grade of 8.3/10. With respect to the students' grades, results were only presented for one academic year, so only preliminary conclusions could be done. These excellent results presented in [9] made this new learning methodology to win awards from the Universitat Rovira i Virgili (*Premi Consell Social a la Qualitat Docent* 2015) and the Generalitat de Catalunya (*Distinció Jaume Vicens Vives* 2015).

Table 1. Weight of evaluation items

Evaluation Items	
Oral Exam (70%)	• 30% First Oral Exam (Modules I & II) • 40% Final Oral Exam (all modules)
Reports from Practical Sessions (PS) (30%)	All practical sessions are rated equally

Because of the above-mentioned results obtained from implementing the above project, we decided to continue developing our laboratory subject, focusing our efforts on improving the evaluation system since, to the best of our knowledge, some of the problems may be solved by simply changing the assessment system. The main objective was **to introduce a set of different assessment methods** combining **formative assessments** (to improve instruction and student learning) and **summative assessments** (to evaluate individual academic achievement). Some of these would be accessed via a set of **e-learning tools**, while others would be based on the traditional **face-to-face method**. The idea was to carefully design a comprehensive assessment program that would balance formative and summative student learning information. Additionally, as stated by Ćukušić in [10], incorporating web tools into the assessment system can be effective in improving levels of student engagement in the learning process, providing a learning-by-doing approach and giving rise to better levels of retention and competence acquisition.

It has long been recognized that one of the biggest influences on a student's approach to their studies is the course's assessment regime [11, 12] and, as stated by Brown [13], assessment is probably the most important thing we can do to get improvements in student performance. Thus, given the acknowl-

edged importance of assessment in shaping the students' approaches to learning, assessment should be a major consideration in any learning and teaching strategy. Many authors suggest that to improve summative assessment we should do more formative assessment, and so the combination of summative and formative assessment seems to be an excellent aid for our subject. Yorke presented in [14] some key features of formative assessment and remarks its importance in students learning and Nicol and co-workers [15, 16] showed how the introduction of these assessments methods helps students take control of their own learning.

As explained by Gareis in [17] while the concept of formative assessment itself is not new, what is new is the evidence of its extraordinary effectiveness in teaching and learning. In their work, Gareis and co-workers presented an in deep review analysis of the research done in this topic concluded that improved formative assessment practices in classrooms typically yield gains in student achievement roughly equivalent to between one and two grade levels in learning. The instructional power of formative assessment is echoed in the well-known meta-analysis of effective instructional strategies led by Marzano and co-workers [18] and in the work developed by Clark [19], who stated that formative assessment reinforces self-regulated strategies among students. According to Clark [19], this formative assessment contributes to improving academic outcomes because students acquire the adaptive and autonomous learning characteristics required for enhanced engagement with the learning process and a subsequent successful performance.

Therefore, the challenge was to carefully design, develop, implement and evaluate a set of different assessment methods based on e-learning tools in combination with traditional face-to-face practical training (essential in this kind of subject) to engage students in the learning process in laboratory subjects in Mechanical Engineering. Once all these new teaching tools have been completely developed and implemented, it is interesting to evaluate this work, monitoring grades and student satisfaction to gauge which of the improvements has been more successful. So that, the aim of this work is to present this new e-learning teaching method based on different assessment activities, carefully measuring and evaluating the results of its implementation in students' engagement and performance.

2. Experimental

2.1 Description of the different assessment methods introduced

To achieve this more interactive teaching system, different assessment methods were introduced to change the previously used system (see Table 1) into this new one. These new methods are presented below (see Fig. 1 for a schematic representation), divided into three main categories (assessing prior knowledge, assessing in practical session and assessing post-knowledge) that combine e-learning strategies with the traditional face-to-face strategy.

All the assessment methods are well distributed in time throughout the semester so as to provide feedback to students when it is most likely to benefit the learning process and when they are still in the process of attempting to master the course material.

1. **Assessing prior knowledge**. Students are assessed individually after they have prepared the next practical session with the aid of the teaching materials (video clips and interactive

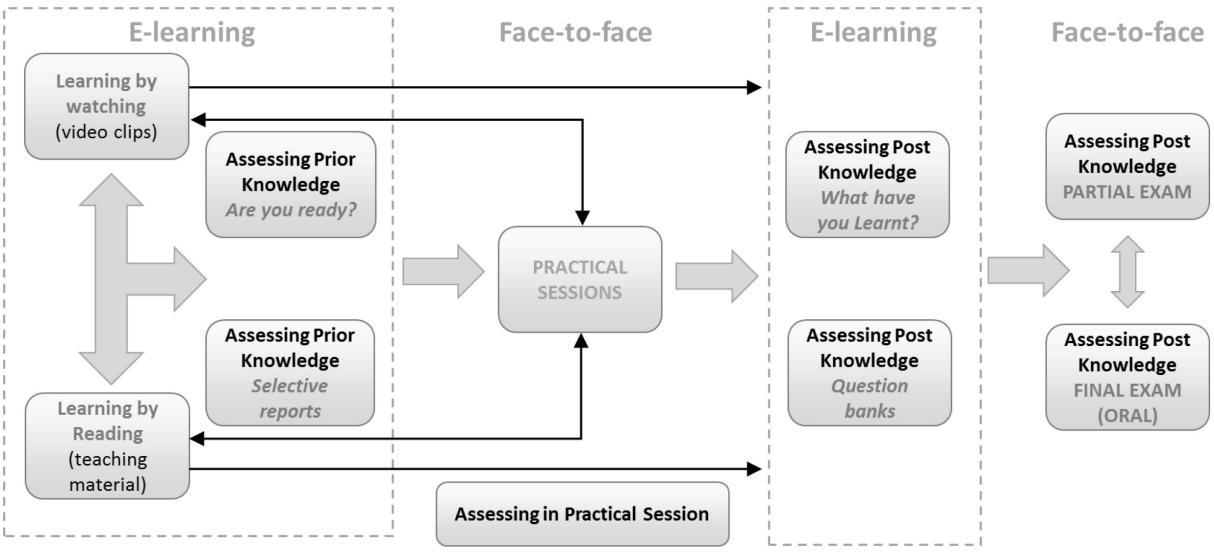

Fig. 1. Schematic representation of the overall teaching method highlighting the different assessment methods.

documents for each PS). The objective with this teaching material is to set the criteria and goal for each PS in as much detail as possible as the first step to using instructional strategies formatively. This idea, as Garrison and co-workers explained [20], engages students in the instruction and learning process by creating clear expectations because they need to understand and know the learning target and the criteria for achieving it. Therefore, some of the questions/exercises focus on knowledge that we consider essential for the successful completion of each PS. Students need to complete them before the corresponding practical sessions and can access them via Moodle. As the practical sessions include theoretical content combined with numerical results that have to be contrasted with the experimental results, this set of assessment methods is divided into two types:

1.1 *Are you ready?* **Self-assessment method.** Multiple choice questions (theoretical content) and numerical questions (relating to the theoretical approach).

1.2 *Selective reports.* Students are asked to calculate and solve some particular exercises in order to contrast them with the experimental results that will be obtained in the next PS.

2. **Assessing in practical session.** Students are put into groups to collaboratively develop the PS. To avoid the main problem with this kind of work (group members not contributing equally), different assessment methods have been implemented which may go at least some way to addressing the problem: some tasks are awarded a group mark (accepting that all members contribute equally) while others are awarded a range of individual marks.

2.1 *Instant report (one group mark).* Instead of students writing up long laboratory reports after the PS, which enables them to hide many of their shortcomings (and obviously takes a long time to mark), they have to submit a much briefer report (using a predesigned pro-forma) as they leave the laboratory. In some PS it may even be possible for teachers to mark it in the laboratory and give feedback before the students leave.

2.2 *Observation (individual mark).* Students are observed while undertaking the lab session. Although this may seem very laborious for the teacher (we have to ask each individual student selected questions about the PS), it is very useful because we can gauge the effectiveness of our teaching methods and the students' learning of the course material. At the same time, we can take advantage of this face-to-face with the student to provide our feedback from previously reported assignments. This weekly feedback is very important because, with longer gaps between handing in the task and receiving feedback, students are less likely to pay attention to it.

2.3 *Part-written practical reports (individual mark).* Students have to complete part of the theoretical explanation and error analysis that is difficult to submit at the end of the lab session. This is only for PS1 and PS2, where an instant report is not enough for acquiring the theoretical or practical understanding of the subject due to the complexity of these PS.

2.4 *Group project (one group mark).* Students are required to design and compute a specific project using the finite element method (this is only for PS12: MEF project). This assessment item can also contribute to developing collaborative and interpersonal skills for group working. However, going more deeply into the benefits of group working lies beyond the scope of the present paper.

2.5 *Oral presentation (individual mark).* For the project described above, students (in groups) are asked to give an oral presentation on their PS12: MEF project. At the end of each group's oral presentation, students are encouraged to give informal feedback and evaluate their peers (peer-assessment). Each individual group member has an individual mark awarded by the teacher and a common group mark obtained from the peer-assessment.

3. **Assessing post knowledge.** Students are assessed individually after they have done the practical session. Some of these post-knowledge methods are designed to help students prepare for the partial and oral exams (the most important in summative assessment), so they focus on concepts that students have to be familiar with by the end of each practical session. These concepts will be discussed in the final oral exam and must therefore be learned in order to achieve the desired learning outcome.

3.1 *What have you learnt? Self-assessment method.* Multiple choice questions and numerical questions for each practical session. The reason for including this set of end-of-PS questions is to ensure that students study each practical session in depth and to motivate and help them to pace their

learning of each PS and give them feedback on it. They are therefore designed to involve analysis, interpretation and understanding of each PS and not only to test superficial learning outcomes or factual knowledge.

3.2 *Question banks.* Students are asked to produce a certain number of multiple choice questions relating to each PS. Asking good questions means that students have to think more deeply, and this helps them to recognize what they do and do not understand about it. This is therefore another aspect of the formative assessment strategy. It also provides the teacher with significant insight into the degree and depth of a student's understanding. Moreover, it is a useful way for teachers to build up a question bank that can be used to update and change the questions in *What have you learnt?*

3.3 *Partial exam.* This includes a combination of short answer questions (useful for assessing a wide range of knowledge across the modules) and multiple-choice questions (similar to *What have you learnt?*).

3.4 *Final exam.* **Viva voce exam (oral).** The student gives a five-minute presentation on one of the practical sessions, chosen at random, and then answers questions from the teaching staff for another five minutes. This is very useful for exploring students' understanding of all the lab sessions and for evaluating essential skills and learning outcomes. In the new assessment process there is only one oral exam instead of the two presented in Table 1.

Not all the assessment methods developed are implemented in all the practical sessions. This is pointed out in Table 2, which also includes the weight of each evaluation item.

All the assessment methods are implemented in the subject's Moodle. Both **self-assessment methods** provide instant feedback and model answers. They can also be attempted an unlimited number of times. This is very important because students can grade their own work, it reduces the time they have to wait to receive feedback and, most importantly, the feedback is not always given by the teachers, who can therefore focus their attention on other assessment methods. As we explained earlier, because formative assessment requires constant constructive feedback, this feedback is also given in the next practical session so that the student can have the opportunity for contact with the tutor to discuss their comments after the work has been assessed.

All the marks that the student obtains over time are systematically included in what is called the "work plan", an individual student record that can be accessed via Moodle. This is also an important instructional strategy that can be used formatively [11, 20] because it helps students to better understand their own learning as evidenced by their classroom work. This process whereby students keep an ongoing record of their work not only engages them but also helps them—more so than a simple "grade"—to see where they started from and the progress they have made towards the learning goal.

2.2 Tools for the analysis

To evaluate and measure the system's success, we selected a group of students who had studied this laboratory subject in the academic year 2014/15 and 2015/16 in order to perform a detailed analysis of their involvement and performance. All participant students of this study were volunteers. The analysis was conducted at the end of the semester, after the final oral exam. In the academic year 2014/15, of the 81 students enrolled in the subject (7 female and 74 male), 26 were volunteers and wanted to be part of the study (2 female and 24 male) but only 20 of them (2 female and 18 male) finalized the subject (completing and delivering all

Table 2. New assessment methods implemented (with weight of each item)

Main Category	Name of the assessment method	Practical Session
Assessing Prior Knowledge (10%)	*Are you ready?*	All PS
	Selective reports	PS6-PS11
Assessing in Practical Session (30%)	*Instant report (one group mark)*	All PS except PS12
	Observation (individual mark)	All PS
	Part-written practical reports (individual mark)	PS1 and PS2
	Group project (one group mark)	PS12
	Oral presentation (individual mark)	PS12
Assessing Post Knowledge (60%)	*What have you learnt? (5%)*	All PS
	Question banks (5%)	All PS
	Partial exam (20%)	PS1 to PS7
	Final exam (30%)	All PS

assignments and assessments). In the academic year 2015/16, of the 69 students enrolled (4 female and 65 male), 35 were volunteers and wanted to be part of the study (4 female and 31 male) and 30 (4 female and 26 male) finalized the subject. To evaluate the relation between the different assessment items, the marks from the students on each assessment item were analyzed and compared using visual inspection of plots and correlation coefficients (Pearson product-moment correlation coefficient [21]).

To evaluate the students' perception and satisfaction, they were also invited to complete a satisfaction survey. The aim was to draw useful conclusions regarding the perceptions and satisfactions of the student group. The survey was conducted via Moodle and contained different questions arranged in four main categories:

- Two questions relating to their satisfaction with the assessment method as a whole, focusing on its quality and usefulness. (*Please, indicate how satisfied you are with the overall assessment method?* and *Please, indicate what is your personal view on the quality and usefulness of the different assessment methods used).* A Likert rating scale was used (0 = very dissatisfied, 5 = very satisfied).
- Questions relating to their satisfaction with the degree of detail in the assessment feedback. (*Please, rate if feedback is sufficiently detailed to enable you to identify particular weakness).* Again, a Likert rating scale was used (0 = not at all, 5 = extremely detailed).
- Questions with closed-answer text to analyze which of the different assessment methods introduced was most highly valued by students. (*Please, select the assessment method you think that engage you the most for the learning objectives).*
- Questions with closed-answer text to analyze their perception of the fairness of the grading process for selected assessment methods. (*How fairly do you fell with the grading process of: Selective reports, Practical Session, Partial Exam, Oral Exam).* A Likert rating scale was used (0 = not at all fairly, 5 = extremely fairly).
- Two questions related to likes/dislikes regarding their experience in using the assessment method as a whole.

The data collected from this survey were analyzed in order to highlight the positive appraisal of the interestingness and usefulness of the different learning tools introduced.

Finally, in order to measure the results of the learning process with the implementation of this interactive teaching system, the students' final grades for the subject were also analyzed, considering the rate of successful task completion (rate of success) and the participation rate (dropout). In this analysis, all the students (volunteers and non-volunteers) were included and the results of the academic courses where the new learning method were introduced (2013/14, 2014/15 and 2015/16) were compared with the two previous ones (2011/12 and 2012/13).

3. Results and discussion

3.1 Students' perceptions and satisfaction

Of the results obtained in the satisfaction survey, we can highlight the positive appraisal of the interestingness and usefulness of the different assessment methods introduced.

Figure 2 presents the detailed results for questions relating to overall satisfaction, quality and usefulness.

The basic results of the first two questions asked (Fig. 2a–b) show that 68% of the students surveyed are very satisfied with the overall assessment method and that 73% of them are also very satisfied with the quality and usefulness of the method. Regarding satisfaction with the assessment feedback, at first glance it can be clearly deduced from Fig. 2c that more than 86% of the students think that the feedback is sufficiently detailed to enable them to identify their own particular weaknesses, and therefore one of our initial goals has been accomplished. Fig. 2d helps us to identify which of the assessment methods engage our students most in the learning process. It is no surprising that the most engaging method (for 40% of students) is "*What have you learnt?*" probably because it is a great help for the partial and oral exams. Students are clearly interested in evaluating their own test results before the exams in order to find out their strengths and weaknesses and become more effective learners. This is also related to the scores obtained in "*Assessment in Practical Sessions*" where, as explained earlier, we aim to provide students with specific individual feedback on particular aspects of their work. In fact, we expected a higher rating for this item, but this is probably related to the different involvement of the five lecturers. As regards the assessment method and the corresponding feedback, a greater number of lecturers would inevitably make it more difficult to maintain marker reliability and consistency. Ways should be found to encourage lecturers to become more involved in the system. This would be an interesting topic to study in greater depth.

The students are far less engaged with the partial and oral exams (obviously!) and completely not engaged with *Question Bank* (0%). The latter method is very useful for the teacher, but it is clear that the students do not feel the same and consider it to be of no use in the learning process.

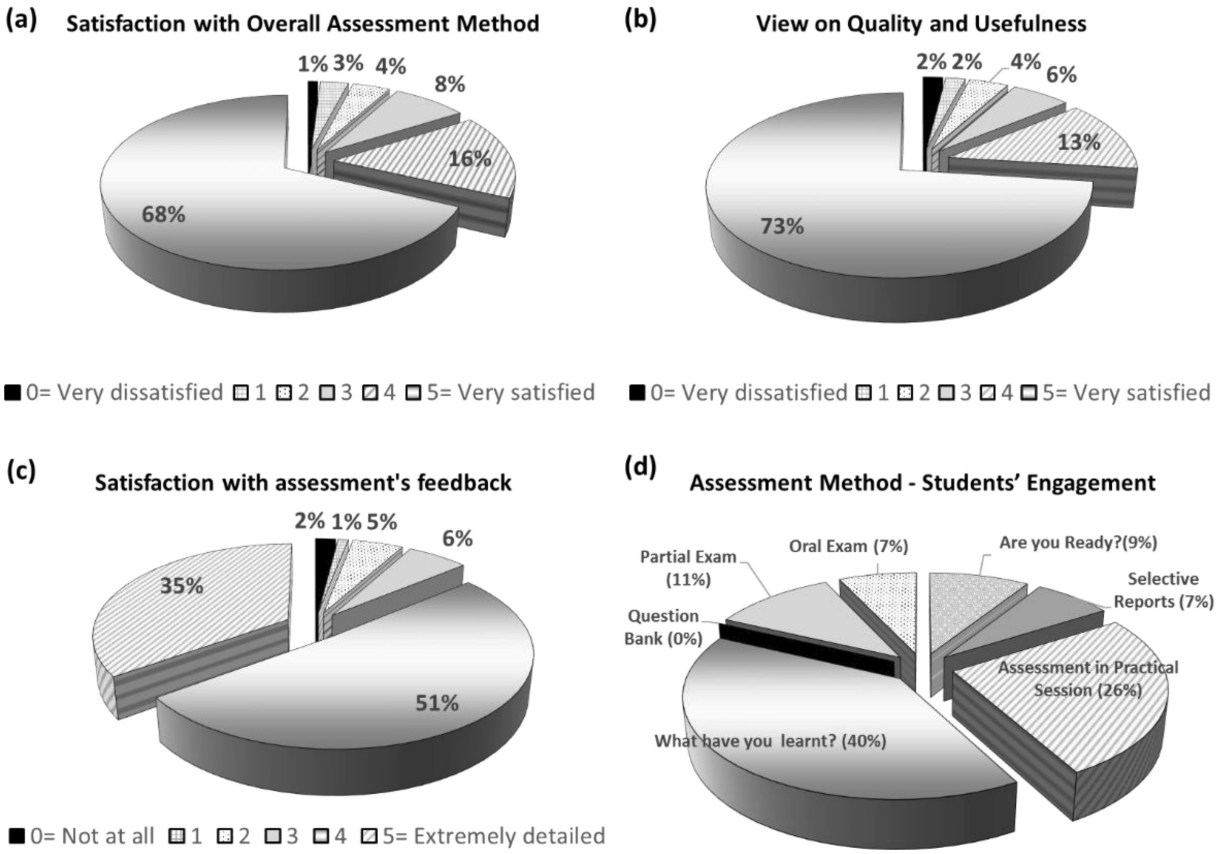

Fig. 2. Students' opinions of different questions about the assessment methods.

A very thorny issue when introducing innovative assessment methods is the student's perceived sense of how fair the grading process is. The most relevant assessment methods were therefore selected to gauge students' perception in this aspect. It is very satisfying to observe in Fig. 3 that two of the four methods selected were considered extremely satisfactory by over half of the students polled, and that the partial exam was considered quite fair or extremely fair by 70% of the students. As expected, students naturally feel under pressure in the oral exam (although it counts for only 30% of the final mark) and their perception of how fair it is differs markedly from the teachers' perception. This effect could perhaps be lessened if we try to give students a detailed explanation as to why they obtained the mark they did, but time limitations (10 minutes per student) make this very difficult.

As for the two open-ended questions in the survey ("*What do you like best about the overall assessment system?*" and "*What do you like least?*"), in an attempt to process the themes that might be present in a mass of text we created a Wordle™ in order to visualize word frequency graphically. Figure 4 presents the results for *likes* and *dislikes* and it is gratifying to see the words that most recurrently appeared: ***different, easy-to-use, advantageous*** and ***time-saving***. These lead us think that our goals have been achieved: the assessment method we introduced has fostered student involvement, the students are clearly satisfied with it and it seems to be effective in improving time-management and study organization.

As far as *dislikes* are concerned, not all the students answered this question (only 55% of students wrote a *dislike* word). Consequently, the negative terms or *dislikes* in Fig. 4 are smaller (because they were used less frequently) than positive ones. The most negative terms repeated were ***laborious***, ***effort*** and ***exhausting*** (representing more than 50% of the total negative terms). This is not surprising. Although previous results may allow us to claim that our assessment methods are effective, the continuous monitoring of students' learning processes means that students have to hand in work every week and, compared to other subjects with traditional summative assessment, they believe that this requires too much effort. But this is the core of formative assessment: success more fairly depends on consistent application and hard work, not a last minute burst of effort. If we compare these student opinions with Fig. 3, we can assert that they perceived these methods as rewarding to those who make a consistent effort to learn rather than to those

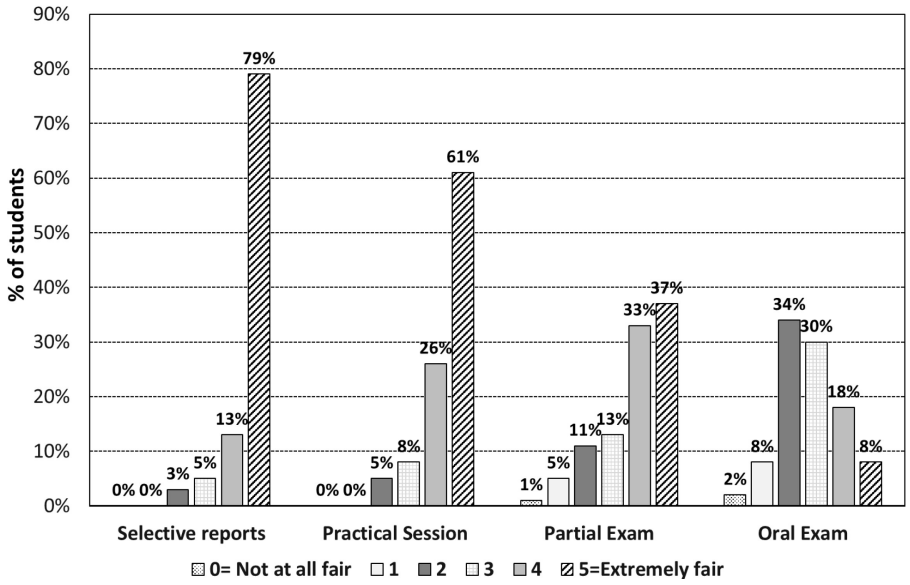

Fig. 3. Fairness of the grading process for selected assessment methods.

Fig. 4. Schematic representation (Wordle^{TM}) of the students' *likes* and *dislikes* as regards the assessment methods.

who rely on cramming or making a last-minute effort.

3.2 Students' grades and correlation analysis

Rate of successful task completion (rate of success) and participation rate (dropout)

To analyze whether our new methodology has helped to increase the rate of success, Fig. 5 presents the grades obtained in the last five academic years, the first two courses where these new assessment methods had not been implemented and the last three ones, where the assessment systems had been completely introduced. This comparison helps to understand the advantages brought by these improvements and to quantify the benefits of their implementation. It is important to note that the results presented in Fig. 5 are for all the students enrolled in the subject, not only the volunteers who, usually, are mostly the better students. Analyzing only volunteers' grades would produce a methodological shortcoming and, consequently, a statistical distortion of the results.

In Fig. 5 it can be appreciated that the results for the first two years were very similar and the grades have risen significantly once the new teaching method has been implemented. The dropout rate (the ratio of students who do not take the exam to the total number of students enrolled in the subject) has been considerably reduced (from 41% in 2011/12 to 18% in 2015/16) as has the number of failed students (from 20% to 11%). By contrast, the number of students achieving good grades (between 7 and 9) has increased noticeably from 3% in 2011/12 to 23% in 2015/16. Finally, the number of students in the highest grade band has grown from 0% to 4% in 2014/15 and 3% in 2015/16. This is not a very high percentage probably due to the use of continuous assessment, which produces a more distributed grade. Based on the results presented above, we can conclude that the effective use of our new assessment activities has had a considerable impact on the dropout rate and on the students' grades.

Once analyzed the academic outputs for all the

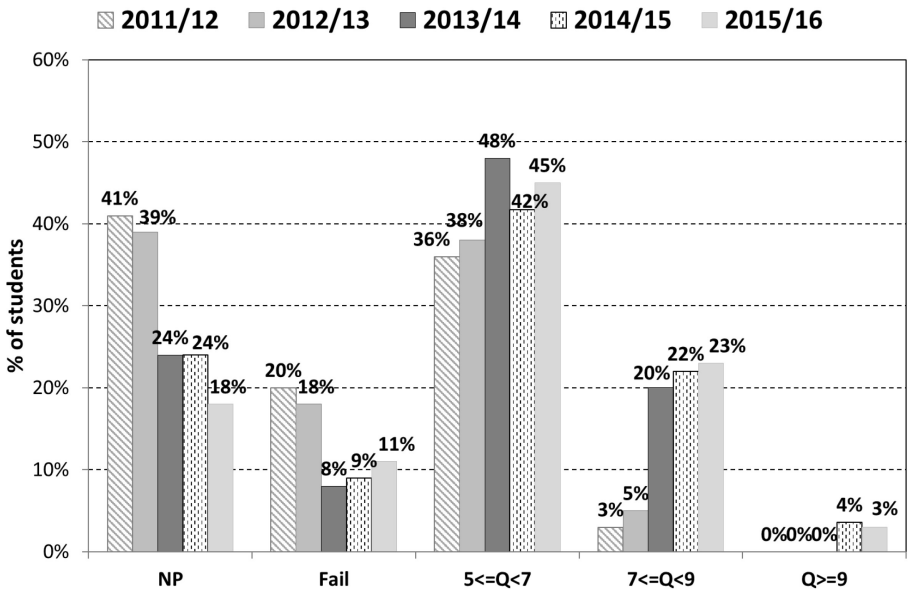

Fig. 5. Grades obtained in the last five academic years.

students, the next goal is to correlate if the students who have actively used these improved teaching methods are those who have obtained better grades. With this aim, we have performed the following detailed analysis with the group of volunteers.

To evaluate the relation between the different assessments items, the marks from the students on each assessment item were analyzed and compared using correlation coefficients (Pearson product-moment correlation coefficient). The results are summarized in Table 3 and presented in Fig. 6 for the two most relevant assessment methods (self-assessment methods prior and post knowledge).

In Table 3 and Fig. 6, *Assessing Prior Knowledge* includes only the marks for Self-Assessment (called *Are you Ready?*) because, as explained in section 2.1, the other assessment item, Selective Reports, is only related with numerical calculus that should be contrasted with the experimental results that will be obtained in the PS. *Assessing in Practical Session (PS)* includes the marks for Instant Report and Observation.

The results show that all the correlation values between the different assessments items are higher enough to pass the hypothesis tests with a statistical significance at the level $p < 0.05$. It is important to note that the correlation between some of them is stronger (with a statistical significance at the level $p < 0.01$) as it is highlighted in Table 3. With respect to the correlation between the self-assessment methods before the practical session (Assessing Prior Knowledge) and the Assessing in Practical Session (where the students can demonstrate partially the understanding of the practical session) we can conclude that our objective of setting the criteria for each PS in as much detail as possible has been achieved, and this self-assessment method prior PS has helped the student to focus on essential knowledge for the successful completion of each PS. This correlation is also plotted in Fig. 6(a). In this figure, data points on the diagonal represent perfect resemblance between both items (assessment prior knowledge and in PS). The more distant a data point is from the diagonal, the less resemblance is present between the two items. It can be observed how most

Table 3. Pearson correlation coefficients of the different assessment methods

	Assessing Prior Knowledge (Self-Assessment)	**Assessing in PS**	**Self-Assessment post PS**	**Partial Exam**	**Oral Exam**
Assessing Prior Knowledge (Self Assessment)	1.000				
Assessing in PS	**0.421(*)**	1.000			
Self-Assessment post PS	0.326(**)	0.303(**)	1.000		
Partial Exam	0.291(**)	0.351(**)	**0.751(*)**	1.000	
Oral Exam	0.287(**)	0.327(**)	**0.580(*)**	**0.505(*)**	1.000

(*) $p_{crit\ (0.01)n\ =\ 50} = 0.361$; (**) $p_{crit\ (0.05)n\ =\ 50} = 0.279$.

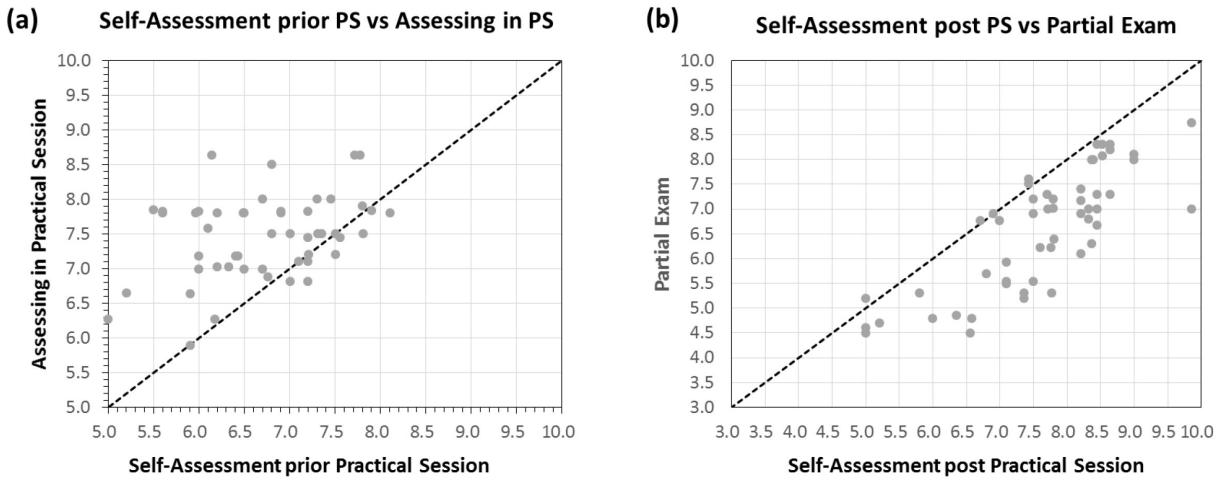

Fig. 6. Comparison of marks between (a) Self-assessment task before PS (*Are you Ready?*) and Assessing in Practical Session and (b) Self-assessment task after PS (*What have you learnt?*) and Partial Exam.

of the points are situated near the diagonal (marks of both items are in the same level) and in the upper side of the diagonal, meaning that marks are higher for Assessing in PS than for Assessment Prior Knowledge. This can be rationalized taking into account that Assessment in PS assesses not only the student's knowledge but also his attitude and aptitude in the laboratory.

Regarding the correlations between the self-assessment tasks after the practical session (*What have you learnt?*) and the partial and oral exams it is noteworthy that they are extremely high (r = 0.751 and 0.580 respectively). The correlation between assessing after PS (*What have you learnt?*) and Partial Exam can also be observed in Fig. 6(b). In this plot, most of the points are near the diagonal but in its lower side, meaning that marks are higher for the self-assessment tasks than for Partial Exam. This is not unexpected because, as explained before, self-assessment methods provide instant feedback and model answers can be attempted an unlimited number of times, so it is logical that marks are significantly higher. These results confirm that self-assessment tasks after the PS are a good guidance for students to know which their level of knowledge before the exams is. It also confirms that students with higher marks on self-assessment tasks are also the ones with higher marks on the exams, which indicates that self-assessment tasks are useful to prepare the partial test exam as well as the final oral exam.

4. Conclusions

Different assessment strategies have been implemented in a laboratory subject in order to improve learning outcomes in Mechanical Engineering while simultaneously engaging students in their learning process. The results of an anonymous student satisfaction survey show that these improvements have been very well received; more than 70% of students are very satisfied with the quality and usefulness of the method and 86% think that the assessment feedback is sufficiently detailed to enable them to identify their own particular weaknesses.

Regarding the fairness of the grading process, most of the assessment methods are considered extremely fair by 60% the students polled. A qualitative analysis of the likes/dislikes of the assessment methods reveals that students are clearly satisfied with them and that they seem to be effective in improving time-management and study organization. It seems that students have been able to take ownership of their learning process and feel engaged in it, so one of our goals of improving the learning outcomes has been achieved. However, they feel exhausted with this continuous monitoring of their learning process. They have to produce a great deal of effort and persistence during task completion, although at the same time they believe that this effort is rewarding and fair. The statistical calculations from the different assessment items show that the correlation values between self-assessment tasks and the rest of the items are statistically significant after the hypothesis test. The most outstanding results are the correlation between the marks for self-assessment before the practical sessions and in practical session and the strong correlation between self-assessment after the practical sessions and the Partial and Oral exam. These results confirm that self-assessment task before PS are a great assistance in understanding what we consider essential for the successful completion of each practical session and after PS are a good guidance for students to know which their level of knowledge before the exams is. It also confirms that students with higher marks on

self-assessment tasks are also the ones with higher marks on the exams, which indicates that self-assessment tasks are useful to prepare the partial test exam as well as the final oral exam. We can conclude that this comprehensive assessment program contributes to improving academic outcomes and ensures that students acquire the adaptive and autonomous learning characteristics necessary for enhanced engagement with the learning process and a subsequent successful performance.

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