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Invigilated Lab Exams as an Effective Strategy to Reduce Academic Dishonesty*

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A new methodology assessment for the laboratory in engineering courses to reduce academic violations is proposed. It is based on invigilated face-to-face practical exams, and it is suggested as an alternative to the conventional laboratory assessment through student reports. This traditional method is sensitive to commit academic violations by students, like cheating, however, with the new proposal, it is drastically reduced. In the new assessment, the laboratory sessions are divided into theoretical-practical and tutorial sessions, when students work by themselves; and test sessions, when invigilated face-to-face practical exams are carried out to assess the laboratory part of the course. In these exams, the students must prove their knowledge in real-time with 100% practical exercises. Before implementing this new methodology, the results in the course under analysis showed that cheating was becoming widespread with a clear increasing tendency. To test the proposed assessment, a comparison between the traditional and the new methodology laboratory assessment is accomplished in a Computer Architecture undergraduate engineering course. Descriptive and inferential statistics are used to analyze the influence of the new assessment on the learning results. The results show that with the new proposal the number of detected copies disappeared, and the withdrawal rate is reduced without having a significant influence on the final mark or the theory mark. Therefore, the new methodology assessment has removed the academic violations without interfering with the learning process of the students.

Keywords: assessment; computer engineering; engineering curriculum; academic dishonesty; computer architecture

1. Introduction

It is a widely held opinion that laboratory work has a very important role in undergraduate engineering courses and graduated programs [1–3]. Engineering is a practical field, and a very important part of the learning process takes place in the laboratory. By real problem-solving techniques student's understanding increases due to the link between theory and laboratory sessions [4–6].

Conventional laboratory assessment in engineering courses has been laboratory reports. This method seems inherently deficient and subjective for several reasons. The reports are a time-consuming task that makes complex the synchronization of lab activities and lectures. This delay may make it difficult to obtain effective feedback for the students [7, 8]. The learning outcomes are not fully attained since analysis or critical thinking skills are not evaluated [5, 9]. Furthermore, reports tend to be ineffective in generating student enthusiasm and passion for learning and therefore decrease the students' motivation [1].

However, to our knowledge, the most widespread derived problem is the conservation of academic integrity. These violations, like cheating, plagiarism, collusion, or contract cheating, are becoming one of the main concerns in higher education around the world. Approximately one-half to three-quarters of university students commit some type of cheating, and with time more and more students commit academic violations [10–14]. This has become an extended problem in higher education but specific cases about some kind of cheating in engineering courses have been found as well [15–17].

Several alternatives for laboratory assessment have been applied in different branches of engineering to minimize the problems caused by conventional laboratory reports. Project-based learning motivates students to learn actively and it is widely used in engineering subjects [1, 18]. Reflective activities in digital and electronics courses showed positives outcomes for engineering students [19]. Other alternatives that produce different results in the learning process have been studied such as model-based inquiry pedagogy on students' inquiry [20]. However, in the last few years, the tendency is the virtualization, both laboratories and assessment, to support the face-to-face classes [5, 8, 21–26].

However, findings indicate that there are no assessment tasks that can, in themselves, eradicate academic violations. It is important to identify and address perceived opportunities to cheat for any assessment task [27], like the virtual laboratories,

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where this risk could be high. One possible way of reducing the likelihood of academic violations is invigilated assessment, such as conventional examinations where techniques to prevent cheating have been proposed [24, 28–30]. In this assessment strategy, it is highly recommended to make a special effort in the exam preparations to improve their effectiveness by the staff involved in the course [31].

Therefore, to neutralize academic integrity violations, the proposal of this paper is a new assessment laboratory methodology based on invigilated face-to-face practical exams, in which the students reproduce the lab tasks, as an alternative to the traditional assessment laboratory reports within the undergraduate engineering lab. The main objective of this work is to compare two laboratory assessment methodologies, the traditional and the new assessment, analyzing the effectiveness of the proposal, proving that it does not influence the final learning of the students.

The rest of this paper is organized as follows. Section II shows the study context of this work with an explanation of the course and the assessment methodology. Section III describes the statistical analysis used. The experimental results, including opinion surveys and marks analysis, are shown in section IV. Section V shows limitations and discussion of results and finally, section VI provides conclusions.

2. Context and Methodology

This section explains a general description of the course and assessment methodology followed in the study that has been carried out.

2.1 Course Description

This section explains the study context of the laboratory where the new assessment methodology has been applied. This laboratory is part of the *Computer Structure* course – a course of 6 ECTS (European Credit Transfer System) – which is set into the second semester in the first year of the Computer Engineering degree and the Double degree of Computer Engineering and Mathematics. These degrees are taught in the Universidad Autonoma de Madrid (UAM).

In this course, through the definition of an instruction set, the data and control path, basic concepts related to the architecture of processors are explained. The students learn to use VHDL, a specific hardware description language, to study the basic arithmetic-logic circuits, mainly during the laboratory sessions. Furthermore, a simple low-level language (assembler) and the elementary memory system are also concepts studied in this course.

Table 1. Laboratories tasks

Task	Title	Weight (%)	Timing (weeks)
1	VHDL Basics	0	2
2	Simplified microprocessor, GPR and ALU	30	3
3	Assembler Programming	20	2
4	Microprocessor design MIPS	50	5

The final mark of the course corresponds 60% to the theoretical part and 40% to the laboratory part. The laboratories in engineering degrees are a very important part of the curriculum, so in this course, they have an important weight of the final mark. It is necessary to pass both parts of the course, lab and theory, to pass the whole course. The theoretical part is evaluated through classical invigilated exams of theory, henceforth theory mark. The lab mark is 100% assessed through invigilated face-to-face practical exams that reduce the academy violations and this is the main novelty of this work. The lab assessment is divided into four different tasks, each one with a different objective and different weight in the laboratory mark as can be observed in Table 1.

The laboratories have weekly two-hour sessions, which are practical experiments that cover all the theoretical concepts taught in lecture sessions, during a total period of 12 weeks. The faculty is a team of 8 professors, 3 of them for the theoretical sessions and 5 lab instructors. The average number of enrolled students in this course is typically 210 every academic year. They are divided into 8 groups of 26 students each to accommodate the available capacity of lab facilities. The large team of professors and the elevated number of students implies a very careful organization of this course.

2.2 Lab Description

The objective of the laboratory classes is to impart hands-on experience with the MIPS processor architecture. Starting with the VHDL basics and a simplified microprocessor architecture where a general-purpose register (GPR) and an arithmetic logical unit (ALU) are designed. Then, the students have an introduction to assembler programming and finally, the complete microprocessor design is reached.

As mentioned, the laboratory program is divided into four different tasks. The first task is an introduction to VHDL, where through the design of a sequential circuit, concepts like reset, clock and chip enable are acquired. In the second task, the main objective is to design a simplified microprocessor, with GPR and ALU, which allows performing only additions between a register and immediate data. Thirdly, students learn assembler programming, practicing concepts like the stack, calling a function, and passing parameters. And finally, the design of a basic MIPS microprocessor is addressed, which is the most important task of the course. Thus, this latter task has the highest weight in the final laboratory mark.

For all tasks, testbenches are provided to verify the proper operation of the students' design. All concepts studied in the laboratory sessions are also explained in the theoretical classes, but during the labs, the students learn how the processor architecture works by implementing it by themselves.

2.3 Lab Assessment Methodology

This study has been carried out during six academic years from 2014 until 2020, divided into two different periods.

During the first period, the academic years 2014–2015, 2015–2016 and 2016–2017, the traditional methodology was applied. It consisted in the conventional assessment lab reports, where the students had to submit a report explaining the process of every task. A typical report in this course is the description of the design, the VHDL code and the results. In this assessment the instructors used the typical ‘‘tutorial-session'' model class: at the beginning of every class a short explanation of the task was provided, and the rest of the session is devoted to solving doubts.

On the other hand, the new proposed assessment has been used during the 2017–2018, 2018–2019 and 2019–2020 academic years. In this new methodology, the laboratory sessions are divided into three categories:

(1) Theoretical-practical sessions (1 week)
The faculty explain the task and the students start working with the new concepts and the design of every block of the microprocessor.

(2) Tutorial sessions (1 or 2 weeks)
The students work on their designs and debug them with the testbenches with non-evaluable exercises. These sessions are specifically dedicated to solving doubts or questions that may arise during the individual work of the students.

(3) Test sessions (1 week)
They consist in a face-to-face invigilated practical exam of 75–90 minutes, which replaces the classical lab report. In these exams, the students must prove their knowledge about every task in real-time to obtain the lab mark. In this session, the students must solve similar exercises to those done in the laboratory, during the *theoretical-practical* and *tutorial sessions*. For these practical tests not only theoretical concepts are assessed through practical exercises but also the use of the software tools is tested. To neutralize potential academic violations like cheating or illegal traffic of information, internet access is filtered by a firewall and only allowed to the task submission webpage. Furthermore, several versions of each test are done to avoid potential violations between different laboratory groups. An example of one of the exercises of this kind of exam is shown in Fig. 1. In this case, it is provided a design of a microprocessor and the students must implement the control unit to implement the instructions of *addi* and *beq*.

3. Research Design

The study is divided into two different periods, which last three academic years each: 2014–2015, 2015–2016 and 2016–2017 when the traditional assessment was applied and the new assessment, when invigilated face-to-face practical test were carried out during 2017–2018, 2018–2019 and 2019–2020. A total of 1264 students participated in the study, the population in every period include 649 and 615 undergraduate students for the first and second periods respectively. Of the total number of students, 1034 students belonged to the Computer Engineering degree whereas 230 belonged to the Double degree of Computer Engineering and Mathematics.

The main objective of this study is to know if the new proposed methodology, which neutralizes academic integrity violations that had become a problem in this course, interferes with the learning results of the students. Then the null hypothesis is: *‘‘There is no difference in the learning results of students between the traditional and new laboratory assessment''.* To answer this question, in the Results section, the marks of the two academic periods have been analyzed. To do it, a descriptive and inferential statistical analysis and some subjective questions are studied to address this hypothesis. Regarding the data collection and their analyses, quantitative data were collected through students' assessment marks, which belong to the theoretical, laboratory and final marks. On the one hand, the descriptive analysis consists of means, standard deviation, and similarity with the ‘‘ideal student performance'', which will be explained in the Results section. On the other hand, the Analysis of Variance (ANOVA), Levene statistic and Welch‘s ANOVA were conducted for each academic year and period to study statistical differences.

The study is performed during six different academic years, and because of this, it was difficult to prepare a specific questionnaire to compare the two

Exercise 1 (3 points):

Design the control unit of the single-cycle MIPS processor to implement the instructions **addi** and **beq**. The interface of this module interface of this module is shown in the attached figure.

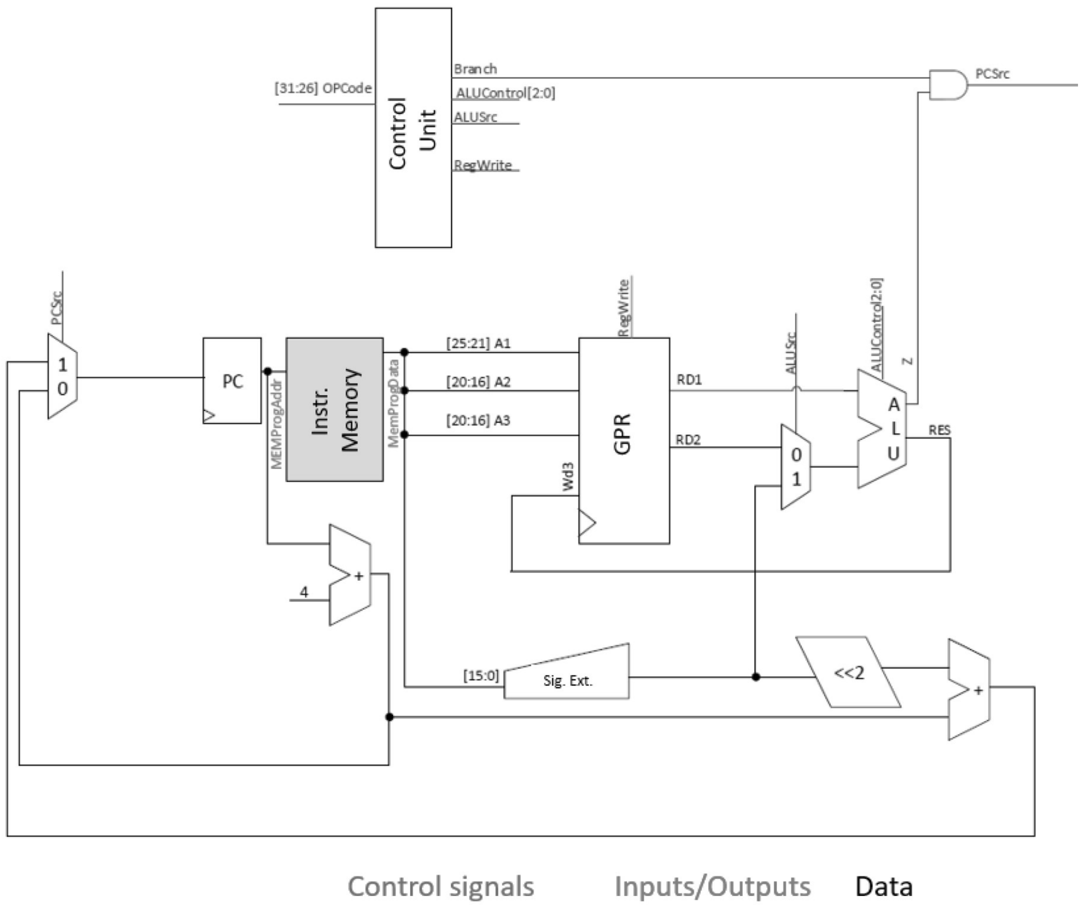
INSTRUCTION	Branch	ALUControl	ALUSrc	RegWrite
addi				
beq				

To make easier the implementation of the unit control:

- **Complete the table** with the values of the control signal for every instruction paying attention to the provided MIPS processor diagram.
- **Implement** the code of the Control Unit (*"ControlUnit.vhd"*) including these control signals and the changes you considered necessary.

To test the functionality of the control unit a testbench is provided *"ControlUnitTb.vhd"*.

(a)



(b)

Fig. 1. Example of one exercise of an invigilated face-to-face practical exam. It consists in implementing the design of a control unit of a single cycle MIPS processor for the instructions *addi* and *beq*. (a) Statement of the exercise (b) MIPS processor diagram.

assessment methodologies since every methodology was used in different temporal periods. However, four questions related to the laboratories have been extracted from the general questionnaires carried out by default to evaluate the teaching activity and some conclusions can be obtained.

4. Results

The results of the research are presented in this section to answer if the new proposal influences the final learning of the students. The marks have been analyzed over six academic years – three with traditional assessment and three with the new one – using the SPSS statistical software to obtain the possible effect of the new methodology.

4.1 Descriptive Statistics

One of the main motivations which led the faculty to change the assessment in the laboratory is the increasing number of copies during the last academic years and the disturbing feeling that cheating was becoming a widespread practice among students. The detected copies were in the lab reports and code that students sent in every task. Table 2 shows that between the years 2014–2015 and 2016–2017 when the traditional assessment was applied, the percentage of detected copies increased by 7.36% and the final mark of the students involved in these academic violations increased by 3 points on a scale of 0–10. The authors of these copies were evaluated with zero in the final mark of the course. With the establishment of the new lab assessment, the number of detected copies was drastically reduced. Indeed, there was no case of detected copy because the invigilated face-to-face exams avoid these violations.

Table 2. Detected copies with the traditional approach

Academic year	Number of copies	Percentage of the total number of students (%)	Mean of the final mark
2014–2015	8	3.80	0.53
2015–2016	11	5.18	2.34
2016–2017	25	11.16	3.25

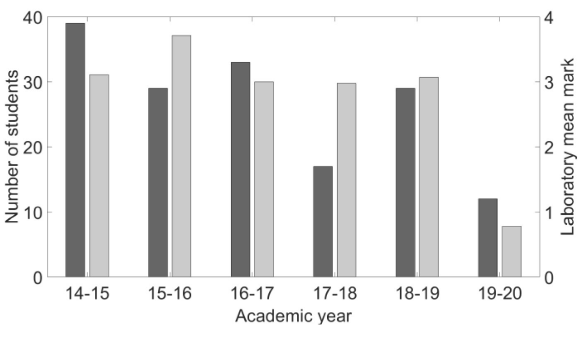


Fig. 2. Number (dark bars) and mean mark (light bars) of students that finished the laboratory part but abandoned the theoretical part of the course.

Fig. 2. describes the number of students who finished the laboratory part but abandoned the theoretical part of this course over six academic years. Both in the traditional or new assessment methodology, these students gave up the theoretical part of the course, without making the theoretical exams. However, in both methodologies, they decided to continue with the laboratory sessions. In the traditional methodology, they were evaluated through reports, that they finished at home, and in the new proposal, they attended the *theoretical-practical, tutorial* and *test laboratory sessions*, obtaining the total lab mark with the invigilated face-to-face practical exams. The main reason for the students for continuing with the labs is because the final laboratory marks are kept until the next exam call in the following academic year. With this study is possible to analyze the ratio between the lab mark and the need for theory concepts to pass the laboratory part of the course depending on the methodology. During the three first years, the period when the traditional assessment was applied, this number of students was between 30 and 40 students. During the new proposal assessment, this number of students was reduced by half, except for the second year of this new methodology. This increment was caused by the repetition of the test models, and more students without knowledge about theory concepts were able to pass the laboratory part, similar to what happened during the traditional period with reports. Furthermore, in this figure, the means of the laboratory marks of these groups of students are depicted showing that the mean with the new assessment was reduced during the two first years of this new period, and drastically reduced in the last academic year when new exam models of the laboratory were used.

Table 3 gives the means and standard deviations of theory and laboratory marks. In the new methodology, the total laboratory and theory marks have been increased by 0.20 and 0.57 points on a scale of 0–10 respectively. This points out that with the new assessment in the laboratory, the students have increased their theoretical knowledge. At first, the face-to-face methodology exams could seem more difficult but the mean in the laboratory mark is slightly higher in this period than with the traditional assessment and considerably higher for theoretical marks. Due to both theoretical and laboratory marks have increased, the hypothesis of better assimilation of concepts by students is reinforced.

Fig. 3 shows the withdrawal rate, which means

Table 3. Means and Standard deviation of Laboratory and Theory Marks

Period	Means, Standard Deviation and Population	Laboratory Mark	Theory Mark
Traditional assessment	Mean	6.64	5.07
	SD	0.35	0.44
	N	649	
New assessment	Mean	6.63	5.64
	SD	0.68	0.29
	N	615	

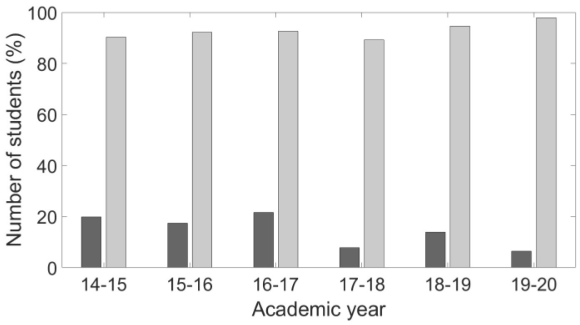


Fig. 3. Withdrawal rate students (dark bars) and Assessed vs. Enrolled rate students (light bars).

the proportion of the students who abandoned the complete course, both theoretical and laboratory parts. This number has been reduced with the new methodology. During the traditional method, the percentages were between 17 and 21% and with the new proposal were between 6 and 13%. Moreover, the number of assessed students versus the total number of enrolled students has a rising trend during the period of the new methodology. This means, the new assessment avoids withdrawal and increasing the number of students who follow the course daily.

Finally, the performance of students relating theory and laboratory marks is analyzed. For every year, the "ideal student performance" has been calculated following the equation (1) (continuous line in Fig. 4).

$$\text{Ideal Lab} = \frac{\text{Lab mean}}{\text{Theory mean}} * \text{Ideal Theory} \quad (1)$$

Where *Ideal Lab* is "the ideal student performance" in the laboratory part, *Lab mean* is the mean value of the laboratory part, *Theory mean* is the mean mark of the theory part and *Ideal Theory* is "the ideal performance" in the theory part. The slope is the relation between the laboratory mean divided by the theory mean every year. Ideally, the perfect student performance should relate theory and laboratory marks with a one slope function (dash line in Fig. 4), that is, if the student obtains a 6 in theory, he/she should obtain a mark around 6 in the laboratory part, according to his/her theoretical knowledge acquired. However, to make a more realistic comparison, the "ideal student performance" has been calculated every academic year, to consider the intrinsic characteristics by year. Moreover, every academic year, there are theoretical values from which the real perfect student would obtain the maximum mark (10 points) in the laboratory part. They are the cross points of the "ideal student performance" (continuous lines) with a 10 in the lab mark axes. These values, which are different every year, are around 7.44 in 2014–2015 up to 9.76 in 2019–2020 (see Fig. 4).

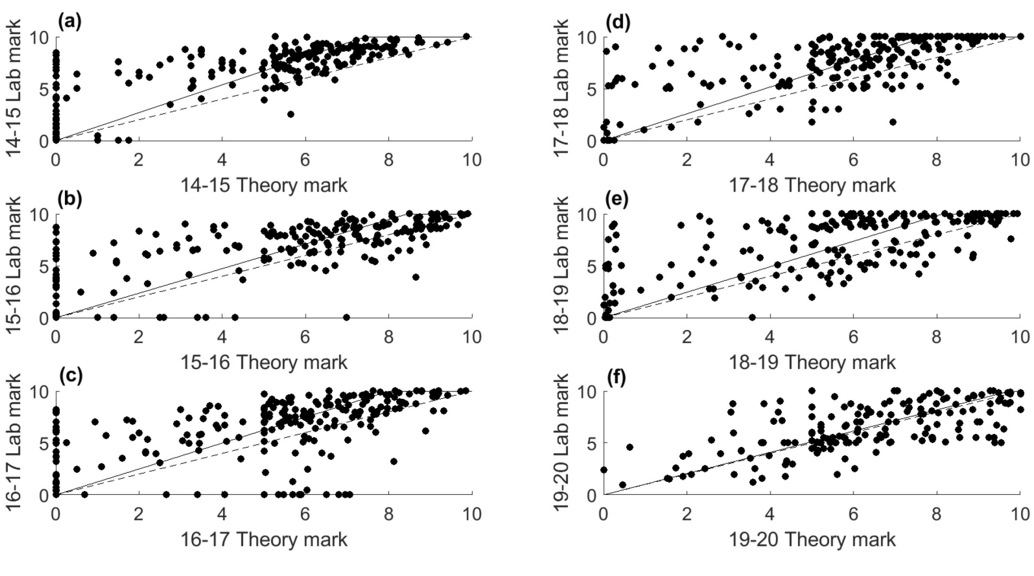


Fig. 4. Theory and laboratory ratio and "ideal student performance". Left column, (a), (b) and (c) is traditional assessment and right column, (d), (e) and (f) correspond to the new assessment.

Table 4. Mean distance to the "Ideal student performance"

Period	Academic year	Mean	SD
Traditional assessment	2014–2015	1.65	1.73
	2015–2016	1.85	1.83
	2016–2017	2.07	2.18
New assessment	2017–2018	1.63	1.76
	2018–2019	1.91	1.72
	2019–2020	1.38	1.23

These differences are caused by the relative difficulty between theory and laboratory parts every academic year. Usually, the total percentage of passing students and the mean marks are higher in the laboratory assessment than in the theoretical one.

Then, Fig. 4 shows the theory and laboratory mark ratio for every academic year. The left column figures, Fig. 4a, b and c, belong to the traditional assessment and the right column, Fig. 4d, e and f, to the new one. Analyzing the distance in the y axes of every point with the "ideal student performance" (shown in Table 4), the methodology assessment can be evaluated.

The traditional period assessment shows a high dispersion, however, in the new methodology, mainly during the years 2107–2018 and 2019–2020 the dispersion and distance around the "ideal student performance" have been reduced. This implies that the tendency of these groups is close to the ideal performance of that year, so the applied assessment is fair. In 2018–2019 the distance and dispersion are again higher since the exam models were repeated from the previous year. In 2019–2020, the laboratory exams were made from scratch, and it is important to highlight that the calculated "ideal student performance" (continuous line) is extremely closer to the ideal perfect student performance (dashed line) with slope 1.

During the traditional period, the number of students with zero points in theory and some marks in laboratories (dots on y-axes in Fig. 4) is extremely high, mainly during 2016–2017, when the number of detected copies was maximum. These students only finished the laboratory part of the course. This number of students and their marks are shown in Fig. 2. These students have been practically removed with the new assessment methodology. This means that with the traditional methodology there was a high number of students, who were able to pass the laboratory part of the course without any knowledge about theoretical concepts. However, with the new assessment, this problem has been solved.

Furthermore, there are some students in the traditional methodology, Fig 4a, b and c, which have zero points in the laboratory and some marks in the theory part (dots on x-axes). These points refer to some laboratory detected copies, which could complete the theoretical part, but they have been penalized in the lab part with zero points or a minor number of students who decided only to complete the theory of the course without the laboratory. During the new assessment period, these students are practically zero.

4.2 Inferential Statistics

To address the null hypothesis, *"No difference in the learning results of students between the traditional and new laboratory assessment"*, the ANOVA test was applied in the final theoretical mark, laboratory mark and final mark. This test analyzes the statistical differences between both periods. The one-way ANOVA analysis was performed at 0.05 p-value significance, which requires the homogeneity of variances of groups. The Levene statistic has been calculated as shown in Table 5, obtaining a p-value of zero for the laboratory and the final mark, so the hypothesis on the homogeneity of variances is rejected for these two groups. However, a p-value of 0.118 is reached for the theoretical mark, therefore the hypothesis on the homogeneity was accepted in this case.

Then, Table 6 shows the results of the one-way ANOVA test for theoretical marks. The table gives the test result as $p = 0.556$, which means that there is not a statistically significant difference between these marks for both periods. This means that the laboratory assessment does not have a significant influence on the theory mark of the students.

Besides, the laboratory and final marks reject the homogeneity test since their variances are unequal,

Table 5. Test of homogeneity of variance

Mark	Levene Statistic	df1	df2	Sig.
Laboratory	85.331	1	1076	0.000
Theory	2.444	1	1076	0.118
Final	12.651	1	1076	0.000

Table 6. ANOVA test results of theory marks

	Sum of squares	df	Mean square	F	Sig.
Between groups	1.467	1	1.467	0.330	0.556
Within groups	4780.960	1076	4.444		
Total	4782.427	1077			

Table 7. Robust test of equality of means (Welch's ANOVA) for laboratory and final marks

Mark	Statistic	df1	f2	Sig.
Laboratory	6.686	1	1016.500	0.010
Final	0.736	1	1072.949	0.391

Table 8. Anonymous opinion survey of the traditional assessment (2014–2015, 2015–2016 and 2016–2017 academic years) and the new assessment (2017–2018, 2018–2019 and 2019–2020 academic years)

Question	Academic year					
	2014–2015	2015–2016	2016–2017	2017–2018	2018–2019	2019–2020
1. Total time for laboratory activities is enough	4.11	4.25	3.99	4.00	4.20	3.76
2. The material resources available for the laboratory activities have been adequate	4.37	4.35	4.20	4.19	4.30	4.10
3. The workload of this course is adequate	4.09	4.27	3.91	4.20	4.53	4.02
4. In general, I am satisfied with this course	4.25	4.36	4.01	4.25	4.33	3.94

therefore the Robust Test of Equality of Means, specifically Welch's ANOVA was applied. Table 7 summarizes the test results with p higher of 0.05 in the final marks, then again, the null hypothesis is accepted for this case, and it can be concluded that there are no significant differences in the final marks between both periods. However, for the laboratory case, the new assessment methodology influences the marks. This is caused because the new methodology has completely changed the assessment method, so, understandably, it has effects on the laboratory mark. Therefore, the new assessment methodology does not have a significant influence on the final theoretical and final mark, but it influences the laboratory assessment.

4.3 Student Satisfaction

At the end of every semester, UAM releases anonymous online general surveys to gather student feedback on every course. From this questionnaire, four specific questions related to the laboratories have been extracted.

The questionnaire consists of a 5-point Likert scale (1 = "Strongly Disagree"; 5 = "Strongly Agree") items designed to measure student perceptions related to the course. The survey was answered by a total of 358 students, 203 from the traditional assessment (29.16% of the students of that period as it was explained in section III) and 155 for the new methodology (26.18% of the students, in this case, see section III). Therefore, the margin of error for this sample is 4.39% with a 95% confidence level.

Table 8 summarizes the results of the anonymous opinion survey. Question 1 is related to the dedicated time to the laboratories, question 2 asks about the resources and material. Finally, questions 3 and 4 ask about the workload and general opinion of this course. The collected student ratings were in most cases above 4, which is positive feedback. In 2019–2020, question 1 obtained a lower punctuation mark than in the rest of the academic years. This can be explained because this year was the most demanding in the laboratories due to the new assessment and exam models. Regarding questions 2 and 3, the student's opinion is maintained along the two periods. As well as in question 1, the last one shows a slightly lower mark in the last academic year. This is probably caused because the laboratory difficulty with the new methodology has increased.

5. Discussion

The increase in the number of copies of lab reports during the last academic years was the main reason to change the assessment methodology in the laboratory part of the course. With the traditional assessment, the percentage of detected copies in the laboratory increased from 3.80% up to 11.16% in three academic years. In the light of these results, it is acceptable to think that there were more non-detected cheats among students like some non-clear copy cases, which were not considered. Furthermore, according to Table 2, the mean of the final mark of the detected copy cases increased by three points, so over time, it seems better students were involved in the copy issues in the traditional assessment. With the establishment of the new assessment with invigilated face-to-face practical exams, the detected copies in laboratories were removed.

Another important point is that the new assessment has helped to reduce the number of students who finished the laboratory but abandoned the theoretical part (see Fig. 2). With the previous methodology, it was relatively easy to complete the laboratory reports, without any knowledge about theory. However, with the new proposal, to pass the laboratory exams without any theory concepts is difficult. The new lab assessment forces students to follow the course daily not as in the previous one. In fact, in Fig. 4d, e and f, it is observed, how with the new assessment the dispersion and distance are reduced, and the performance is closer to the "ideal student performance". Indeed, the number of students of the traditional assessment who abandoned the theory part depicted in Fig. 2 are directly related to the students in Fig. 4a, b and c, who have zero points in theory and some marks in laboratories (dots on y-axes in Fig. 4 left column). The new methodology helps to link the theory and practical concepts studied in the course and forces the students to follow both parts in parallel. As consequence, the new assessment avoids withdrawal, increasing the number of people who study the course daily. Furthermore, theoretical and laboratory marks have increased and therefore better assimilation of concepts is reinforced by results. Finally, the inferential statistic shows the laboratory assessment of this work does not have a significant influence on the theory or final marks. Thus, the new assessment methodology does not interfere in the assimilation of concepts, however, reduces drastically the number of copies.

To the best of the authors' knowledge, there are not many published works to study the benefits of invigilated exams as a strategy to reduce copies compared with the traditional lab assessment of reports. Some alternatives to the traditional reports are found in [5, 9, 30]. Vargas et al. [9] propose the Portfolio Method, which enhances the quality of student writing through the process of revising versus the traditional reports. Chen et al. [5] also propose a laboratory pedagogy interweaving weekly student portfolios with onsite formative electronic laboratory assessment. However, both methodologies become difficult to implement when the number of students is high because it requires several processes of review and immediate feedback of student work. On the other hand, similar conclusions to our work can be found in [30], which combines unsupervised and invigilated assessment. They concluded the invigilated tests seem to be a more accurate method of ongoing assessment than the take-home task used as unsupervised assessment. They solve their concerns about plagiarism, adding a short in-class test that assesses working knowledge of the same concepts than in the take-home task.

5.1 Limitations

Although implementing the new assessment of practical invigilated exams helps to reduce the number of violations without influencing the learning results, the authors did not obtain this conclusion with students in the same academic year, with a control group. The study was carried out during six academic years: during the first period, 2014–2015, 2015–2016 and 2016–2017, the traditional methodology was applied, and 2017–2018, 2018–2019 and 2019–2020 the new proposal. The control group would have implied an unfair assessment among students of the same academic year, which is not allowed in this university.

One limitation of this new methodology is the theory exam was the same for all students in every academic year, however, the laboratory exams were different but with similar complexity. This new proposal implies more time required from faculty, due it is necessary to create several versions of the laboratory exams for the different lab sessions, which take place in several timetables. Another point is the high number of instructors in the laboratory part, which also can influence the lab mark. Both factors could impact the marks of the course, so they should be investigated. One suggestion to address these limitations is to assign all lab groups to the same professor in a unique timetable. However, the high number of students, the faculty, the laboratory classes and the timetable are out of our control, and they are imposed by the head team.

Regarding student satisfaction, the authors did not track the effect of the new assessment with a dedicated questionnaire with specific questions about the methodology. This might be addressed in a future study. Another limitation of this questionary is that was impossible to make a comparison between the two methodologies assessment among the same group of students because they were implemented in different academic years.

6. Conclusion

Laboratory reports make easier the violation of the academy integrity if they are used to assess the practical part of the curriculum in engineering courses. A practical example is the course under study. To reduce the increasing number of detected copies, a new laboratory assessment methodology has been proposed. This methodology is based on practical invigilated face-to-face exams as an alternative to the traditional assessment of laboratory reports. A comparison of both methodologies is done to identify if the new proposal interferes with the learning results of the students. Before the new methodology, the detected copies increased around 7.5% in the last academic years, however, once the proposal is applied, the detected copies disappeared. Besides, the number of students that exclusively finished the laboratory part was reduced by half and the withdrawal rate has been also decreased below 13%. Finally, the statistical analysis shows how, with the new proposal with invigilated exams, the student's performance mark is closer to the "ideal student" in 11.85%. Moreover, the inferential statistics shows the new assessment methodology does not have a significant influence on the theoretical, and final marks. Therefore, the findings of this work show that the new methodology helps to reduce drastically the academic violations without interfering with the final learning results of the students.

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