International Journal of Engineering Education Vol. 35, No. 3, pp. 766–778, 2019
Printed in Great Britain
0949-149X/91 $3.00+0.00
© 2019 TEMPUS Publications.

A Comparison of Portfolio and Final Test Scores as a Predictor of Final Course Grade*

J. M. FERNÁNDEZ ORO, A. MEANA-FERNÁNDEZ**, R. BARRIO PEROTTI, J. GONZÁLEZ PÉREZ and E. BLANCO MARIGORTA
Fluid Mechanics Area, Department of Energy, University of Oviedo, C/Wifredo Ricart s/n Gijón Asturias 33204 Spain.
E-mail: andresmf@uniovi.es

In this work, two different evaluation methods are presented from laboratory sessions in the Fluid Machinery and Systems course of the Bachelor Degree Program in Mechanical Engineering: evaluation of technical reports (individual portfolio of the students) and final test (single objective assessment). The statistical analysis of the data during the last five academic years for 684 students reveals that the portfolio evaluation is less correlated with the final grade of the subject, showing overrated marks with narrow dispersions. On the contrary, the final test evaluation exhibits a higher correlation with the final grades, presenting a more representative distribution. The evaluation based in a final test is found to be more significant, unbiased, more coherent and able to reduce the subjectivity observed in previous years with the reports-based evaluation.

Keywords: laboratory evaluation; practicum test; final grade; mechanical engineering

1. Introduction

In the context of technical degrees, and especially in the field of Engineering, it is common that the different subjects conforming the curricula include practical tasks in the organization of the face-to-face learning activities [1–3]. The weight of these practical activities in the final assessment of the student depends on several factors such as the degree of practicality of the subject, the module the subject belongs to (mandatory or optional, basic or specific, common-core or specializing), the number of students and professors, or even the type of degree (bachelor, master or doctorate).

Logically, depending on the weight assigned to the evaluation of the lab sessions, as well as the percentage of the course load they represent (as much in the amount of students as in the amount of objectives and associated learning results), the system employed for their assessment will be more or less thorough. In fact, the practical content of a subject might be the fundamental core of evaluation (i.e. when it is necessary to confirm that some particular practical competences have been acquired), or just a complementary part, when the subject is more theoretical or conceptual. In any case, the development of a methodology for the evaluation of the practical contents of a subject is a difficult and complex task. Firstly, due to the nature of the practical sessions, which may be very diverse [4]: demonstrative or participative lab sessions, computer practical sessions, classroom sessions, field work, workshop sessions, etc., but also due to the available means that condition the way the practical sessions are developed: individual or group-based, the number of sessions and their intensity. In addition, the number of participating students, as well as the number of groups and professors (also if the professors are from different occupations), might complicate the coordination and evaluation of the practical sessions substantially.

Generally, the evaluation method for the practical sessions should be capable of verifying that the skills acquired by the students are enough to prove that they fulfill the objectives and learning outcomes associated to these sessions [5] Regarding the literature, there are many possibilities for the assessment of lab sessions in engineering [6–8]. Obviously, it would be ideal to schedule personalized evaluation sessions with executional practical tests, but this is not feasible in many situations due to the lack of time and means. Instead, practical written exercises that emulate the conditions of the practical sessions may be posed to evaluate how the students solve the practical executional process and the results they obtain. As an intermediate solution, as a deferred evaluation, a portfolio may be used, so every student presents one or several reports which summarize the tasks performed and discuss critically some final conclusions. Afterwards, the professor designs an evaluation rubric to assess the different portfolios.

The evaluation system based in portfolios [9, 10] is a less demanding system than a final test, which often entails a higher degree of subjectivity for the

** Corresponding author.

* Accepted 20 January 2019.

grading of the reports. It is a commonly employed method when the weight of the practical contents in the subject is not very pronounced (up to 25% of the final mark) and when there is a great number of professors involved in the evaluation. The design of an adequate rubric system, based in an accurate definition of the questionnaires to be filled in [11, 12], may reduce the degree of subjectivity, but it is not simple to reduce the bias associated to the personal criteria of each particular evaluator.

On the other hand, a final test is a more objective methodology, but it is also more demanding for the students. It is a method traditionally employed when the weight of the practical contents in the subject is preponderant [13]. The design of the test must guarantee that the student is able to reproduce the contents learned in the practical sessions in equivalent conditions to those experienced during the realization of the sessions. Particular care must be taken regarding the contents of the test, avoiding the introduction of complexities and additional elements to those present during the practical sessions.

Another option for the assessment of lab sessions is an online assessment based on online tests that the students may complete during the lab sessions or at a separate session once all the lab sessions have been performed [14, 15]. The introduction of ICTs in the lab sessions is also useful to collect information about the perceptions of the students about the design and realization of the lab sessions [15, 16], or to enhance experiential learning in the laboratory [17, 18].

From the literature analysis, it has been observed that two main evaluation methods are typically employed for the assessment of lab sessions in engineering courses: either the realization of portfolios (individually or in teams) or a final test comprising the contests covered in the sessions. In this work, these two evaluation methods were analyzed for the lab sessions of the subject Fluid Machinery and Systems of the third year of the Bachelor Degree in Mechanical Engineering of the University of Oviedo. After three years (2013/14, 2014/15 and 2015/16) using individual portfolios for the evaluation of the lab sessions, a progressive decline in the quality of the reports, as well as mark distributions with low dispersion and generally overrated values, were detected. Additionally, different evaluation criteria were found among the professors (up to 9 different professors involved in the grading of the lab sessions), so it was decided to substitute this evaluation system with a final evaluation session in which a written test was performed (2016/17 and 2017/18). In the following sections, the results obtained after the statistical analysis of the lab session marks are presented, which confirm a reduction in the degree of subjectivity with the final test method, resulting in more dissimilar mark distributions and with generally lower marks.

2. A case study: the subject Fluid Machinery and Systems

Fluid Machinery and Systems is a mandatory subject comprising 6 European Credit Transfer and Accumulation System (ECTS) credits, placed in the first semester of the third year of the common-core module of the Bachelor Degree in Mechanical Engineering of the University of Oviedo, imparted in the Polytechnic School of Engineering of Gijón. The objectives of the subject are to provide the students with the knowledge of the working principles and applications of fluid machinery and to introduce them into the fluid transport, power transmission, propulsion and energy conversion technologies, as well as other applications of Fluids Engineering. The subject is imparted in both Spanish and English for the students choosing the bilingual group of the Bachelor's Degree.

The subject comprises 150 h of personal work of the student: 60 h are face-to-face work (28 h of lectures, 14 h of seminars, 14 h of lab sessions, 2 h of group tutorials and 2 h of evaluation sessions) and 90 h are distance work (usage of virtual campus and individual work). For the final assessment of the subject, the lab sessions (15%) and a series of proposed activities (elaboration of preliminary designs for small installations), with other 15%, are considered. Finally, an exam at the end of the subject represents the remaining 70% of the mark.

Usually, the subject has 150 students per year and a passing rate slightly over 60% (performance rate). The students tend to perceive the difficulty of the subject as relatively low, so they maintain a positive attitude and are convinced to be able to pass the subject relatively easily. Moreover, the course syllabus is relatively short and with homogeneous and progressive contents, facts that make following the course and understanding the course contents easier. In addition, the basis for this subject has been already introduced in the mandatory subject of Fluid Mechanics in the second year, with a lesson setting the theoretical basis for the subject. Hence, the subject is conceived as an "extension" of concepts learned by the students in previous years, facilitating substantially the learning process and feeding the confidence of the students back. It should be stated that the number of hours of the subject is large enough, so it is possible to advance steadily and smoothly throughout its different aspects.

Table 1 shows the evolution in the number of students enrolled in the subject during the last five

Table 1. Evolution of the academic performance indicators of the subject Fluid Machinery and Systems (years 2012/13 to 2017/18) in comparison with the totals of the degree

Academic Year		**2012/13**	**2013/14**	**2014/15**	**2015/16**	**2016/17**	**2017/18**
Fluid Mach. and Systems	Students	64	136	165	129	156	128
	PR	62.3%	62.1%	61.0%	60.8%	63.8%	32.8% (*)
	SR	74.5%	70.3%	72.0%	69.6%	77.4%	56.0% (*)
	ER	83.6%	88.3%	84.7%	87.3%	82.5%	58.6% (*)
Bachelor in Mech. Eng.	Students NE	222	227	242	196	177	168
	PR	51.3%	59.6%	59.6%	59.2%	61.4%	NA
	SR	64.3%	69.8%	71.9%	71.7%	73.9%	NA
	ER	79.7%	85.4%	82.9%	82.6%	83.1%	NA

(*) Provisional results (only results from the first call available). NE: New Enrollment Students. NA: Non-available data.

years, altogether with the main academic performance indicators: the performance rate PR (passed credits/enrolled credits), the success rate SR (passed credits/evaluated credits) and the evaluation rate ER (evaluated credits/enrolled credits). Additionally, the total data for the Bachelor Degree in Mechanical Engineering are provided to place the subject in its context. It must be noted that the indicators of the subject are higher than the mean of the degree.

In parallel, to observe the degree of satisfaction of the students with the subject, Fig. 1 shows the results of the General Virtual Survey (EGEred 2016/17)) for a total of 91 answers over 156 enrolled students (significant answer rate 58.3%). The mean satisfaction rate of the subject is perfectly aligned with the typical values of the degree and the learning program is positively rated, clearly over the mean values of the degree. Nevertheless, the guidance and the practical contents of the subject have lower ratings, probably as a consequence of the high number of professors involved in the lab sessions, the number of students groups (eight) and even the disparity between the different timetables to adjust the sessions to the course planning.

3. Analysis of the practical contents of the subject

The syllabus of the practical contents comprises the realization of three sessions: (1) Oleohydraulic bench; (2) characteristic curve of the centrifugal pump and (3) Characteristic curve of an axial fan. The sessions are held in the teaching laboratory of the Fluid Mechanics Area of the Department of Energy from the University of Oviedo, placed in the East Building of the Polytechnic School of Engineering of Gijón. Due to the great number of enrolled students, the 8 student groups (PL-1 to PL-8) are subdivided into subgroups A and B, resulting a total of 16 subgroups. Finally, each subgroup is divided into two teams (a and b) who

Number of answers: 91	LEARNING PROGRAM					GUIDANCE		LAB SESSIONS		SATISFACTION		
Questions → / Choices ↓	1. Information	2. Contents	3. Evaluation system	4. Virtual Campus	AVERAGE Learning Program	5. Assistance and follow-up from professors	AVERAGE Guidance	6. Practical activities	AVERAGE Lab Sessions	7. Learning	8. Usefulness of learned knowledge	AVERAGE Satisfaction
8-10	43	41	38	49		34		46		43	42	
5-7	42	44	34	34		39		29		40	40	
3-4	3	2	5	4		11		6		6	6	
0-2	0	1	3	2		2		8		2	2	
Number of answers	88	88	80	89		86		89		91	90	
Average value	7,40	7,23	6,95	7,47	7,27	6,80	6,80	6,97	6,97	7,08	6,99	7,03
Average for the degree	7,24	7,47	7,14	7,02	7,22	7,12	7,12	7,14	7,14	6,85	6,86	6,86

Fig. 1. Satisfaction ratings of the learning program of the subject (Snapshot from EGEred 2016/17).

perform the lab sessions the same day, but independently. These last teams are formalized in the first lab session.

Typically, the first session is held in the weeks 40–42 of the year, the second during weeks 43–45 and the third in the weeks 46–48 (approximately). Finally, from 2016/17, a group tutorial for evaluation has been added to the program (around week 49 of the year), in which a final test of the lab sessions is performed.

The first session consists on the construction of simple oleohydraulic circuits which allow to answer a simple questionnaire about their behavior. The second and third sessions consist on obtaining the characteristic curves of pumps and fans, measuring their performances in terms of delivered flow rate and pressure as well as power consumption. In these cases, the measurement methods proposed by the international standards are employed.

Regarding the evaluation of the practical sessions, until academic year 2015/16, this evaluation was performed based on the portfolios delivered by the students [19, 20]. Particularly, in the document that regulates the sessions, attached to the course description [21], the following system is proposed:

> "During each session, every student must perform the calculations and tasks associated to the corresponding session individually. Every doubt or problem may be discussed with the professor in charge of the session during its realization. The calculations and results will be collected in a handwritten template, which will be given to the professor at the end of the practical session (i.e., no further deliveries will be allowed). Given the case, the professor will hand back the report to the student for him/her to correct the possible mistakes or scarcities. Once the report is delivered, the professor will proceed to its evaluation. Each student will obtain a final mark for the practical sessions, as a result of the mean of the marks for each particular session. The final mark will have a maximum value of 1.5 points, that will be added to the final test mark, which will have a maximum value of 7.0 points."

Subsequently, after 2016/17, after detecting a lack of uniformity in the evaluation criteria, the evaluation method based on portfolios is substituted with a final test evaluation. Hence, the new text regarding the evaluation of the practical sessions is changed into the following (the changes from the previous version are highlighted):

> "During each session, every student must perform the calculations and tasks associated to the corresponding session individually. Every doubt or problem may be discussed with the professor in charge of the session during its realization. The calculations and results will be collected in a handwritten template, *which will be kept by the student at the end of the practical session (i.e., no report will be collected by the professor). Given the case, the professor will highlight the possible mistakes or scarcities in the reports for the students to correct them and understand their significance. In the last week of the term, an evaluation session will be held as a group tutorial. Every student will be allowed to bring the reports from the lab sessions, as well as the session guides and the studying material that they consider convenient (lecture slides, solved problems, sheets with formulas). Every student will answer a simple questionnaire to evaluate his/her understanding of the content of the lab sessions. Finally, a mark for the practical sessions will be obtained as a result of only the evaluation of this questionnaire.* The final mark will have a maximum value of 1.5 points, that will be added to the final test mark, which will have a maximum value of 7.0 points.".

Fig. 2 has been added to provide a clearer view of the full procedure for the evaluation of the lab sessions, from the lab session itself to the obtainment of the final mark by the students. At every lab session, after the pertinent explanations from the professors, the students proceed to perform the corresponding experiment (in Fig. 2, the pump testing bench is displayed as an example). Then, the students post-process the measurements obtained and perform the necessary calculations to get the results required at the lab session scripts. Finally, they generate a lab session report, collecting all the measured data, the calculations and their own conclusions. Afterwards, the correction of the reports by the professors follows. In the portfolio-based evaluation method, each session report would get a mark based on its content, and then a final mark for every student would be obtained as an average of the particular marks, as described in Fig. 2, left. With the later evaluation method based on a final test, all the lab sessions reports are still being corrected by the professors, but they are not graded and then filed. On the contrary, they are returned to the students so that they can use them as a study material for the final test that will evaluate their learning results from the lab sessions (Fig. 2, right). Hence, this final test mark will directly represent the final mark for the part of the subject corresponding to the lab sessions. Annexes I (example of a lab session report) and II (example of a lab session evaluation final test) have been added as examples of the real reports and tests used in class. It may be verified that no additional contents or more difficult tasks have been added to the final test in comparison with the lab session reports. This ensures that the students will be able to reproduce the contests learned from the lab sessions in equivalent conditions as the ones experienced during the sessions themselves.

4. Lab session groups and results 2013/14 to 2015/16

In this section, the results from the laboratory marks obtained during 3 academic years (2013/14, 2014/15 and 2015/16) with the portfolio evaluation method are analyzed. Firstly, Table 2 shows the

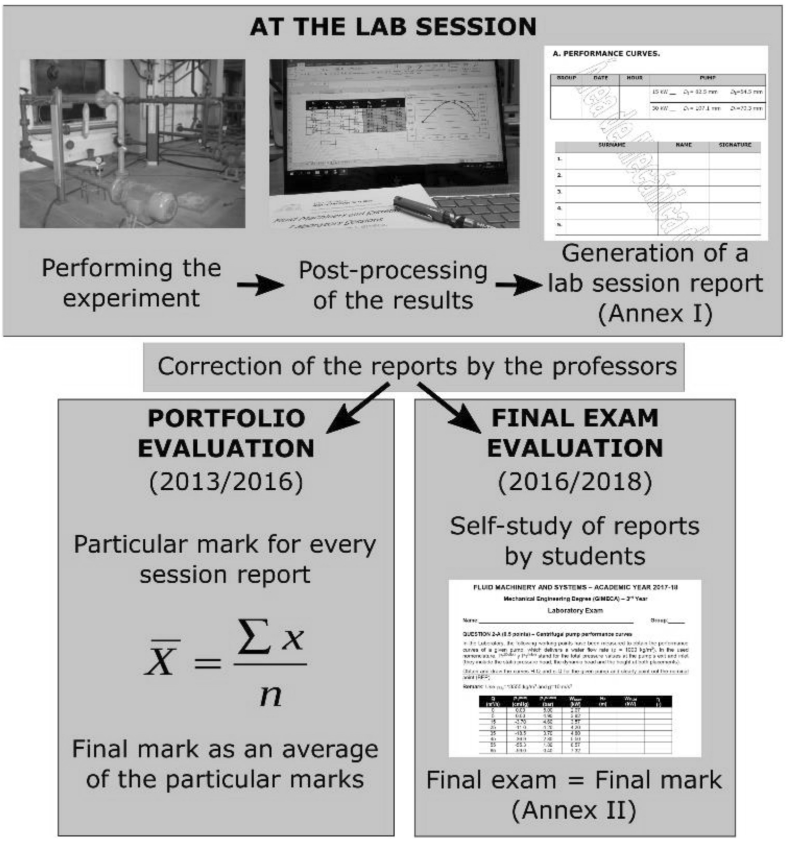


Fig. 2. Procedure for the evaluation of the lab sessions: 2013/16 and 2016/18.

Table 2. Arrangement of the groups for the practical sessions during academic years 2013/14 to 2015/16

Academic Year	**2013/14**		**2014/15**		**2015/16**	
Group	**Students**	**Prof.**	**Students**	**Prof.**	**Students**	**Prof.**
PL-1	13	RBP	18	BGH	10	MGV
PL-2	16	JMC	16	BPG	15	PGR
PL-3	16	JFO	14	RBP	14	MGV
PL-4	15	JMC	18	BPG	16	PGR
PL-5	13	JMC	19	MGV	16	KAD
PL-6	14	RBP	16	BPG	12	KAD
PL-7	16	EBM	18	MGV	14	MGV
PL-8	13	EBM	19	MGV	16	MGV
Average/Total	**14.5**	**4**	**17.2**	**4**	**14.1**	**4**

number of students in each group. Additionally, the professors responsible for each group are identified (with the initials). The mean number of students per group during those years was 15.2, an adequate value regarding the 16 students foreseen at the beginning of the academic year. The number of students was slightly higher in the period 2014/15, as a consequence of a rise in the enrollment. It must be noted that during those years, around 4 professors were responsible of the 8 groups.

Table 3 shows the average marks (M_A) of each group during those years, as well as the standard deviation (σ) to illustrate the dispersion in the marks. Specially from the annual average values (last row of the table), an evident uniformity may be appreciated, with typical characteristic values. Particularly, the total average of the marks from those three years would be fixed to **1.29** $\pm$ **0.15**. Additionally, from the results of Table 3, it has been attempted to find some kind of correlation between the group marks and the number of students, the academic year, or the professor responsible of the lab sessions. The 24 (8 groups during 3 years) average marks and standard deviations have been considered and their correlation coefficients have been calculated with respect to the following vari-

Table 3. Marks of the groups for the practical sessions during academic years 2013/14 to 2015/16

Academic Year	**2013/14**		**2014/15**		**2015/16**	
Group	**M_A**	σ	**M_A**	σ	**M_A**	σ
PL-1	1.35	0.13	1.23	0.16	1.40	0.09
PL-2	1.28	0.14	1.24	0.10	1.22	0.21
PL-3	1.26	0.10	1.31	0.14	1.34	0.06
PL-4	1.26	0.05	1.25	0.12	1.29	0.18
PL-5	1.20	0.24	1.31	0.12	1.22	0.09
PL-6	1.39	0.06	1.19	0.15	1.22	0.14
PL-7	1.39	0.17	1.28	0.17	1.35	0.15
PL-8	1.33	0.24	1.29	0.11	1.30	0.16
Average/Deviation	**1.31**	**0.16**	**1.26**	**0.14**	**1.29**	**0.16**

Table 4. Analysis of the correlation factors in the marks of the practical sessions, 2013/14 to 2015/16

Academic Years 2013/2016	**Correlation coefficient, r(*), with respect to:**	
Factor	**Average mark (M_A)**	**Standard Deviation (σ)**
Number of students per group	**–0.32**	–0.05
Group timetable (group ID, PL-1 to 8)	0.09	0.25
Professor (9 professors identified)	**0.75**	0.01

(*) The correlation coefficient is defined as: $r = \sum(x-\bar{x})(y-\bar{y})/\sqrt{\sum(x-\bar{x})^2 \ \sum(y-\bar{y})^2}$.

ables: (1) number of students, (2) professor and (3) number of group (equivalent to timetable), trying to find any underlying correlation that could highlight a hidden bias in the evaluation (external to the students themselves). The most outstanding facts (see Table 4) are that a slight negative correlation (-0.32) appears between the number of students in a group and the average mark of the group (the less students in a group the better the mark of the group) and an important correlation (0.75) arises between the average mark of the group and the professor responsible of the evaluation (however, the standard deviations do not show these relationships), confirming that there is a significant bias depending on the professor responsible of the evaluation of the portfolio.

On the other hand, not only should the evaluation results be tested as a function of factors external to the students, but also the own motivation and responsibility of the students should be considered. Although a direct analysis is not possible, it is interesting to compare the marks from the practical sessions with the marks obtained a posteriori in the final exam of the subject. Thereby, for instance, Table 5 shows the average mark and the deviation observed in the practical sessions (in bold) for two distinct control groups: the students that finally passed the exam of the corresponding call and the students that failed it. The results clearly show the total independence of the mark of the practical sessions with respect to the final mark of the exam: 1.30 ± 0.16 for the students that passed the final exam and 1.29 ± 0.16 for the students that failed it. In other words, the mark of the practical sessions is not reflecting that their evaluation is significant for the learning process, as the students obtain the same mark independently of the result of the final exam of the subject. In Fig. 4 (left) the scatter plot shows the relationship between the practical session marks (vertical axis) and the final exam marks (horizontal axis) of every student for a total of 190 students who finally passed the exam of the subject (times signs) and 279 who failed (plus signs). The square dots represent the average value of every control group.

Table 5. Marks of the practical sessions for the students depending on the result of the final exam of the subjects — academic years 2013 to 2016.

		Academic years 2013–2016	
Final exam result	**Type of evaluation**	**Average Mark (M_A)**	**Deviation (σ)**
Pass	Practical sessions (0 to 1.5 points)	**1.30**	**0.16**
	Final exam (0 to 10 points)	5.14	1.05
Fail	Practical sessions (0 to 1.5 points)	**1.29**	**0.16**
	Final exam (0 to 10 points)	2.10	0.97

5. Lab session groups and results 2016/17 to 2017/18

This section shows the results from the marks of the practice sessions obtained during 2 academic years (2016/17 and 2017/18) using the evaluation system based in a final test. The test consisted in the construction of the performance curves of the turbomachines from simulated data from measurements obtained in the laboratory. To reduce the level of demand, the students were allowed to use all kinds of support material during the test (lecture notes, books, lab session guides, etc.).

As in the previous section, the arrangement of the groups for the practical sessions are shown (Table 6), collecting the number of students and professors (with their initials). In this occasion, the average number of students per group was around 13.3, slightly lower than the reference value of 16 students, as a logic consequence of the decrease in the new enrolled students observed in Table 1. During these years, an average of 5 professors were responsible for the 8 groups.

Table 7 shows the average marks (M_A) and the standard deviations (σ) obtained by the students in each group during the last two academic years. An important decrease in the average mean of the marks is observed, as well as a significant increase in the dispersion of the marks, breaking the excessive uniformity observed with the previous evaluation system. Particularly, the total average mark of the practical sessions would be fixed to $\mathbf{1.07 \pm 0.32}$.

In addition, the data from Table 7 have been also employed to look for correlations of these new marks with some of the factors analyzed previously. Thereby, Table 8 reveals that there is still a slight negative correlation with the number of students per group and a new slight negative correlation with the group ID appears. In any case, the most relevant fact is the observed decrease in the correlation with respect to the professor evaluating each group (0.47), which allows to conclude that the bias

Table 6. Arrangement of the groups for the practical sessions during academic years 2016/17 and 2017/18

Academic Year	**2016/17**		**2017/18**	
Group	**Students**	**Prof.**	**Students**	**Prof.**
PL-1	16	MGV	13	MGD
PL-2	11	PGR	12	RBP
PL-3	12	MGV	13	MGV
PL-4	16	AZL	12	RBP
PL-5	13	KAD	13	BDP
PL-6	16	MGV	14	AGS
PL-7	11	PGR	11	PGR
PL-8	17	MGV	13	MGV
Average/Total	**14.0**	**4**	**12.6**	**6**

Table 7. Marks of the groups for the practical sessions during academic years 2016/17 and 2017/18

Academic Year	**2016/17**		**2017/18**	
Group	$\mathbf{M_A}$	σ	$\mathbf{M_A}$	σ
PL-1	0.98	0.26	1.23	0.41
PL-2	1.23	0.16	1.13	0.31
PL-3	1.04	0.27	1.11	0.29
PL-4	1.17	0.19	0.98	0.34
PL-5	1.03	0.33	1.40	0.09
PL-6	0.87	0.30	0.97	0.32
PL-7	1.02	0.40	1.07	0.40
PL-8	0.95	0.38	1.00	0.33
Average/Deviation	1.02	0.32	1.13	0.32

Table 8. Analysis of the correlation factors in the marks of the practical sessions, 2016/17 and 2017/18

Academic Years 2016/2018	**Correlation coefficient, r, with respect to:**	
Factor	**Average mark (M_A)**	**Standard Deviation (σ)**
Number of students per group	**–0.35**	–0.10
Group timetable (group ID, PL-1 to 8)	**–0.41**	0.32
Professor (9 professors identified)	**0.47**	–0.02

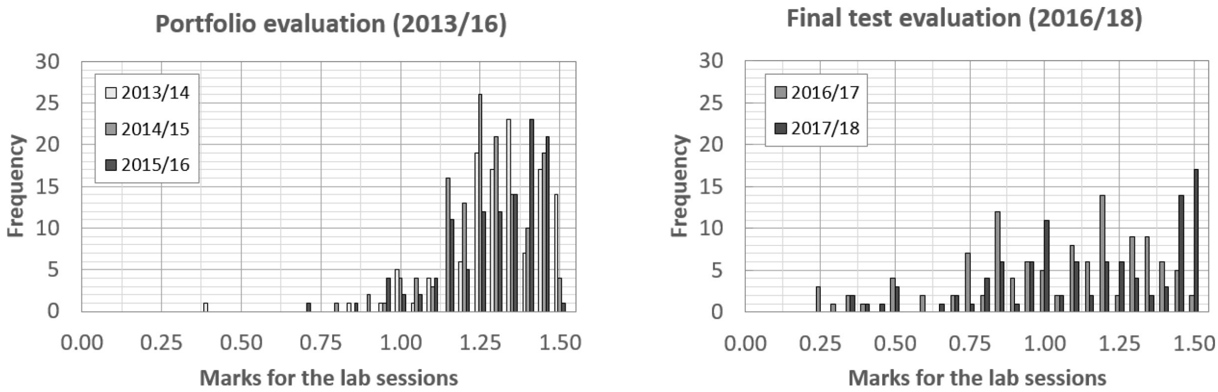


Fig. 3. Comparison of the histograms of the marks for the lab sessions: portfolio (left) and final test (right) evaluation methods.

associated to the personal evaluating criteria of each professor has been substantially mitigated.

In order to highlight the way the final test for the practical sessions has improved the distribution of marks, Fig. 3 shows the comparison of the histograms of the marks with both systems. The marks have been grouped in blocks with a width of 0.05 points. On the left, the results of the evaluation using the portfolio method evidence the low dispersion of the marks and the overrating of the average marks. On the other hand, on the right, the evaluation using a final test seems to yield higher dispersions and a lower average value for the marks, more reasonable in line with what is expected from the practical session groups.

The last part of the analysis is performed in Table 9, comparing again the average marks obtained in the practical sessions by the students that have passed the final exam of the subject and the marks from the students that have failed it. Apart from the important deviation that may be found now, the most noteworthy aspect is that the marks have become more significant, so that the students that pass the final exam also obtain higher marks in the practical sessions. A difference of almost 0.15 points of 1.5 is obtained (from 1.16 for the passing students to 1.02 for the failing ones). This means practically a 10% difference, in contrast with the non-existent difference observed with the method based on portfolios.

As a final remark, these new results are compared in the graphic representation conceived for Fig. 4. In

Table 9. Marks of the practical sessions for the students depending on the result of the final exam of the subjects—academic years 2016 to 2018

		Academic years 2013–2016	
Final exam result	**Type of evaluation**	**Average Mark (M_A)**	**Average Mark (M_A)**
Pass	Practical sessions (0 to 1.5 points)	**1.16**	**0.25**
	Final exam (0 to 10 points)	5.00	0.94
Fail	Practical sessions (0 to 1.5 points)	**1.02**	**0.38**
	Final exam (0 to 10 points)	2.38	0.87

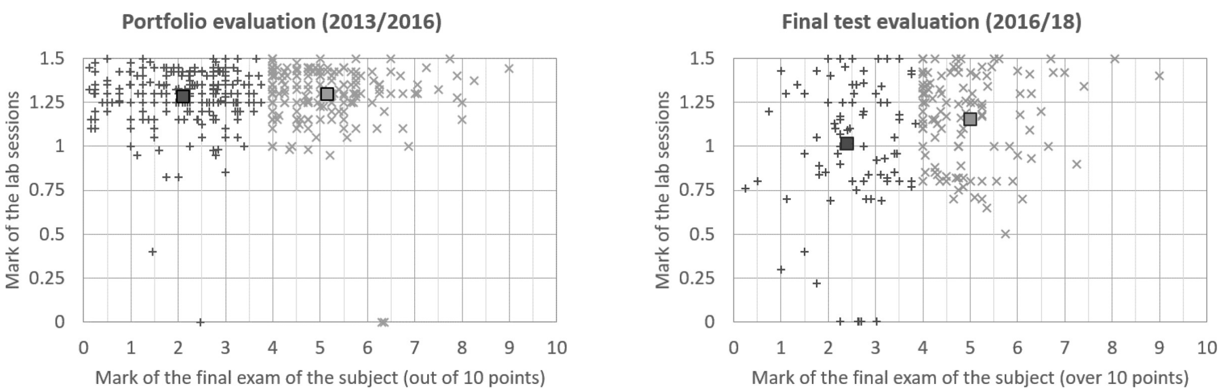


Fig. 4. Comparison of scatter plots of the lab session marks as a function of the result of the final exam of the subject (pass—times signs, fail—plus signs). Note that the passing grade has been set to 4 points out of 10.

this occasion, data from 116 students that passed the final exam of the subject (times signs) and 99 students that failed it (plus signs) have been collected. In Fig. 4 (right) a much more disperse mark distribution is observed with no doubt, with average values notably dissimilar between passing and failing students.

6. Discussions

In this work, the distribution of marks for the practical sessions of the subject Fluid Machinery and Systems has been analyzed. The practical sessions of this subject, from the third year of the Bachelor Degree in Mechanical Engineering of the University of Oviedo, represent 1.5 points over the total final mark. The marks obtained by 684 students during the last 5 academic years have been considered, using two different evaluation systems: evaluation of portfolios from the practical sessions (2013 to 2016) and evaluation by means of a final test (2016 to 2018).

The results highlight that the evaluation system based on portfolios is characterized by mark distributions with low dispersion and generally overrated (1.29 ± 0.16), with notable biases depending on the professor responsible of the evaluation (positive correlation of $r = 0.75$). In addition, it has been observed that the evaluation of the practical sessions is not significant for the learning process of the students, as the group of students that finally fails the final exam of the subject obtains on average (1.29 ± 0.16) almost the same mark as the group of students that finally pass the subject (1.30 ± 0.16).

On the other hand, the evaluation by means of a final test has allowed to reduce the excessive uniformity of the marks from the previous system, increasing the dispersion and containing the grading of the practical sessions (1.07 ± 0.32). Additionally, the bias observed with respect to the professor responsible of the evaluation has been substantially reduced (correlation of $r = 0.47$). Finally, an improvement in the evaluation regarding significant learning has been also observed. The group of students that finally passed the subject had a notably better average mark (1.16 ± 0.25), a 10% higher, than the group of student that failed the final exam of the subject (1.02 ± 0.38).

Hence, the evaluation with a final test seems to be more significant, eliminating different biases, reducing the subjectivity observed during the preceding years and providing mark distributions more coherent and adequate. This study was limited to only one subject from the department, so future work could consider implementation of this method in other courses with different conditions (number of students, typical performance rates) to observe whether the final test evaluation methodology is useful in these cases. It should be highlighted as well that the portfolio method could be implemented again in the future with a new rubric for the correction that could reduce subjectivity. Additionally, even if the final test evaluation method has been found more significant, the results should be monitored in the following years, leading to a possible modification in the method in case the tendency of the marks changes.

7. Conclusion

There are two main evaluation systems typically employed for the evaluation of laboratory sessions in engineering courses: evaluation of technical reports (portfolios developed by the students) and realization of a final test comprising the contents covered during the sessions. In this work, the results from these two different evaluation methods were analyzed for 684 students of a Fluid Machinery and Systems course. It was found that using a final test evaluation was more significant, unbiased and more coherent, reducing the subjectivity observed with the portfolio-based evaluation.

Acknowledgments—This work has been supported by the "FPU" predoctoral research scholarship provided by the Spanish Ministry of Education, Culture and Sports.

References

1. N. Edward, The role of laboratory work in engineering education: student and staff perceptions, *International Journal of Electrical Engineering Education*, **39**, pp. 11–19, 2002.
2. L. Feisel and A. Rosa, The role of the laboratory in undergraduate engineering education, *Journal of Engineering Education*, **94**, pp. 121–130, 2005.
3. D. Ionescu, The importance of working integrated learning and relevant laboratory experiments in engineering teaching, *Procedia—Social and Behavioral Sciences*, **174**, pp. 2825–2830, 2015.
4. F. Alam, *Using technology tools to innovate assessment, reporting and teaching practices in engineering education*, IGI Global, Hershey, PA, USA, 2014.
5. R. Sandler, Beyond feedback: developing student capability in complex appraisal, *Assessment & Evaluation in Higher Education*, **35**(5), pp. 535–550, 2010.
6. S. S. Rathod and D. R. Kalbande, Improving Laboratory Experiences in Engineering Education, *Journal of Engineering Education Transformations*, **Special Issue,** pp. 1–9, 2016.
7. D. Julie and R. Barry, *Improving the Undergraduate Laboratory Learning Experience Through Redesigned Teaching and Assessment Strategies Integrating Transferable Skills and Focusing on Feedback*, Learning, Teaching & Technology Centre, Dublin Institute of Technology, pp. 1–8, 2010.
8. H. Hassan, J.-M. Martínez, C. Domínguez, A. Perles and J. Albaladejo, Innovative Methodology to Improve the Quality of Electronic Engineering Formation Through Teaching Industrial Computer Engineering, *IEEE Trans. of Education*, **47**(4), pp. 446–452, 2004.
9. O. Birgin and A. Baki, The Use of Portfolio to Assess Student's Performance, *Journal of Turkish Science Education*, **4**(2), pp. 75–90, 2007.
10. S. Elango, R. C. Jutti and L. K. Lee, Portfolio as a Learning

Tool: Student's Perspective, *Annals Academy of Medicine Singapore*, **34**, pp. 511–514, 2005.
11. M. E. Fay, N. P. Grove, M. H. Towns and S. L. Bretz, A rubric to characterize inquiry in the undergraduate chemistry laboratory, *Chemistry Education Research and Practice*, **8**(2), pp. 212–219, 2007.
12. A. Jonsson and G. Svingby, The use of scoring rubrics: Reliability, validity and educational consequences, *Educational Research Review*, **2**, pp. 130–144, 2007.
13. I. Pardines, M. Sanchez-Elez, D. A. Chaver Martínez and J. I. Gómez, Online Evaluation Methodology of Laboratory Sessions in Computer Science Degrees, *Revista Iberoamericana de Tecnologías del Aprendizaje*, **9**(4), pp. 122–130, 2014.
14. H. Zhou, Z. Lei, W. Hu, Q. D. D. Zhou and Z.-W. Liu, A Multi-criteria Method for Improving the Assessment of Students' Laboratory Work Using Online Laboratory, *International Journal of Engineering Education*, **33**(5), pp. 1654–1663, 2017.
15. S. De La Flor, A. Belmonte and A. Fabregat-Sanjuan, Improving Students' Engagement and Performance Through New e-Learning Tools in Laboratory Subjects in Mechanical Engineering, *International Journal of Engineering Education*, **34**(4), pp. 1273–1284, 2018.
16. J. Baughman, L. Hassall and X. Xu, Student Perceptions of Flipping a Mechanical Engineering Design Course, *International Journal of Engineering Education*, **33**(5), pp. 1575–1585, 2017.
17. F. Geng and F. Alani, Use of Multimedia for Experiential Learning in Engineering Technology Labs, *International Journal of Engineering Education*, **34**(4), pp. 1192–1198, 2018.
18. E. Kim, L. Rothrock and A. Freivalds, An Empirical Study on the Impact of Lab Gamification on Engineering Students' Satisfaction and Learning, *International Journal of Engineering Education*, **34**(1), pp. 201–216, 2018.
19. R. Choate and K. Schmaltz, Design, build and test in a thermal fluids laboratory course, *Proceedings of the 2005 ASEE 112th Annual Conference & Exposition for Engineering Education*, Portland, Oregon, USA, Jun. 2005.
20. B. Johnson and J. Morphew, An analysis of recipe-based instruction in an introductory fluid mechanics laboratory, *Proceedings of the 2016 ASEE 123rd Annual Conference & Exposition for Engineering Education*, New Orleans, Louisiana, USA, Jun. 2016.
21. Polytechnic School of Engineering of Gijón, University of Oviedo, Course description of Fluid Machinery and Systems of the Bachelor Degree in Mechanical Engineering, http://www.epigijon.uniovi.es/index.php/ver-todos-los-grados/37-grado-ingenieria-mecanica/1837-grado-en-ingenieria-mecanica-guias-docentes, Accessed 10 January 2019.

Appendix 1 Example of a lab session report

A. PERFORMANCE CURVES.

GROUP	DATE	HOUR	PUMP
			15 kW __ D_I = 82.5 mm D_E=54.5 mm
			30 kW __ D_I = 107.1 mm D_E=70.3 mm

	SURNAME	NAME	SIGNATURE
1.			
2.			
3.			
4.			
5.			

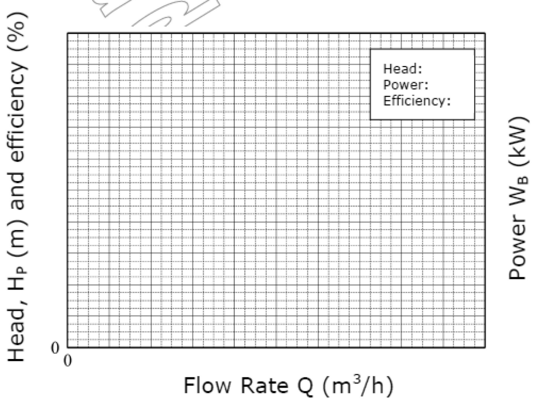
POINT	Variable: Δh Unit:	Variable: P_I Unit:	Variable: P_E Unit:	Variable: W_M Unit:
1	0			
2				
3				
4				

Área de Mecánica de Fluidos

Área de Mecánica de Fluidos

5				
6				
7				
8				
9				
10				
11				
12	Δh_{MAX}=			

POINT	Q (m^3/s)	Q (m^3/h)	P_I (Pa)	P_E (Pa)	H (m)	W_H (kW)	W_P (kW)	η (%)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								



B. UNCERTAINTY ANALYSIS.

VARIABLES UNCERTAINTY				
U (P_S), (Pa)	U (P_E), (Pa)	U (Δh), (m)	U (Q)(*), (m^3/s)	U (Δz), (m)
			$U(Q)=\frac{1}{2}k_{PLATE}\frac{\sqrt{\frac{\rho_{Hg}-\rho_{H_2O}}{\rho_{H_2O}}}}{\sqrt{\Delta h(m)}}U(\Delta h)=$	0.001

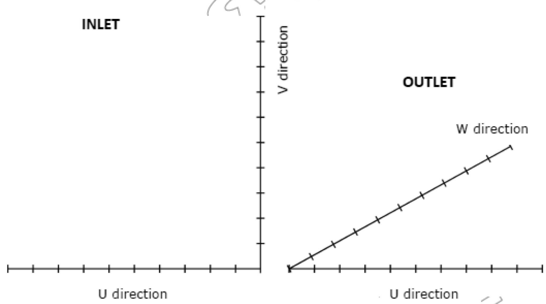
(*) The flow rate uncertainty can be obtained from equation 1, just using the procedure described in section 5.

	CALCULATION OF THE COEFFICIENTS				
	Q_N, (m^3/s)	$\partial H/\partial P_E$	$\partial H/\partial P_I$	$\partial H/\partial Q$	$\partial H/\partial(\Delta z)$
NOMINAL POINT					
		$\partial H/\partial P_E \times U$ (P_E)	$\partial H/\partial P_I \times U$ (P_I)	$\partial H/\partial Q \times U$ (Q)	$\partial H/\partial(\Delta z) \times U$ (Δz)
U (H)=					

C. VELOCITY TRIANGLES FOR THE NOMINAL FLOW RATE.

The last part of the session consists on the drawing of the velocity triangles in the nominal working point of the tested pump, using the following sheet. Besides, the theoretical head using equation 6 and compare it with the experimental value.

PUMP	Q_N, (m^3/s)	r_1, (mm)	r_2, (mm)	b_1, (mm)	b_2, (mm)	V_{1r}, (m/s)	V_{2r}, (m/s)	ω, (rad/s)	U_1, m/s	U_2, (m/s)
15 kW —		55	80	29	18			305.8		
30 kW —		55	100	29	16.7			308.4		



(*) **Important:** keep the same scale for the three components U, V and W.

Q_N, (m^3/s)	U_2, (m/s)	V_{2U}, (m/s)	H_{th} (eq. 6), (m)	H (eq. 2), (m)	H/H_{th}, (%)

Annex II: Example of a lab session evaluation final test

UNIVERSIDAD DE OVIEDO

Page 2/3

UNIVERSIDAD DE OVIEDO
Área de Mecánica de Fluidos
E.P. de Ingeniería de Gijón

FLUID MACHINERY AND SYSTEMS – ACADEMIC YEAR 2017-18

Mechanical Engineering Degree (GIMECA) – 3rd Year

Laboratory Exam

Name:________________________________ **Group:**______

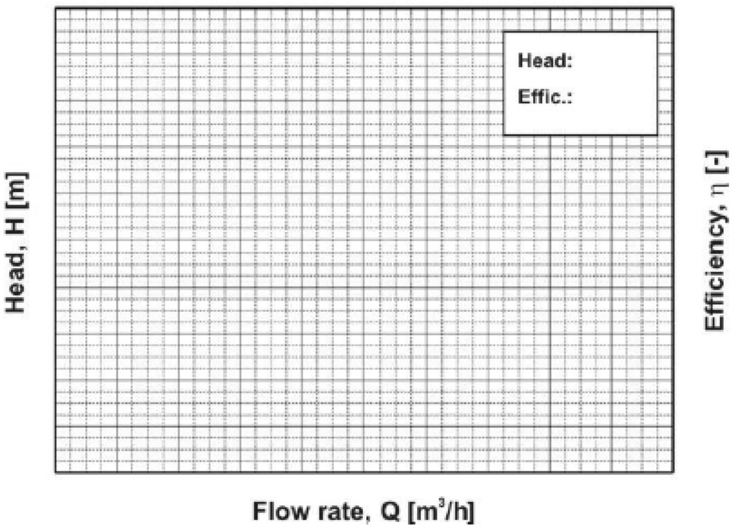
QUESTION 2-A (0.5 points) – Centrifugal pump performance curves

In the Laboratory, the following working points have been measured to obtain the performance curves of a given pump, which delivers a water flow rate (ρ = 1000 kg/m^3). In the used nomenclature, $P_T^{(Outlet)}$ y $P_T^{(Inlet)}$ stand for the total pressure values at the pump's exit and inlet (they include the static pressure head, the dynamic head and the height at both placements).

<u>Obtain and draw the curves H-Q and η-Q for the given pump and clearly point out the nominal point (BEP)</u>.

Remark: Use ρ_{Hg}=13555 kg/m^3 and g=10 m/s^2.

Q (m^3/h)	$P_T^{(Inlet)}$ (cmHg)	$P_T^{(Outlet)}$ (bar)	W_{Shaft} (kW)	H_P (m)	W_{Fluid} (kW)	η (-)
0	0.00	5.00	2.07			
5	0.00	4.90	2.82			
15	-3.70	4.60	3.57			
25	-11.0	4.20	4.20			
35	-18.5	3.70	4.80			
45	-36.9	2.80	5.50			
55	-55.3	1.80	6.57			
65	-59.0	0.40	7.32			



Jesús Manuel Fernández Oro is an associate professor in the Energy Department at the University of Oviedo in Asturias (Spain). After receiving his PhD in Mechanical Engineering in 2005, he has been involved in teaching Fluid Mechanics and Fluid Machinery Systems for graduate and undergraduate courses and Flow Simulation in Master's degree, with more than 3000 teaching hours during the last fifteen years. In addition, he has published more than 40 articles in scientific journals and participated in more than 60 national and international conferences. These contributions concern applied and fundamental investigations on unsteady turbomachinery flows and turbulence, development of measuring techniques in fluid mechanics and also computational modelling of industrial flows.

Andrés Meana-Fernández received the MSc Degree in Industrial Engineering (specialty Energy and Fluids) from the University of Oviedo in 2014 and the MSc Degree in Mechanical Engineering (specialty Mechatronic) from the Clausthal

University of Technology in 2015. Currently, he is a PhD Candidate in the Fluid Mechanics Area of the University of Oviedo. Awarded a predoctoral scholarship from the Spanish Ministry of Education, Culture and Sports, his main topics of interest are energy, fluid mechanics and aero- and hydrodynamic applications. He is also really interested in teaching and innovative methods for teaching-learning, wanting to pursue an academic career after completing his PhD.

Raúl Barrio Perotti received the MSc Degree in Industrial Engineering from the University of Oviedo in 2003 and the PhD degree in 2007 from the same University. He has been a Lecturer at University of Oviedo (Spain) since year 2007. He has participated in several research projects about the CFD simulation and analysis of turbomachinery and industrial flows. His current research interests are focused on the numerical simulation of unsteady flows in turbomachinery, the prediction of dynamic load due to rotor-stator interaction in centrifugal pumps, and the generation of acoustic perturbations. He is author and co-author of more than 50 publications in scientific journals and conference proceedings.

José González Pérez obtained his MSc Degree in Mechanical Engineering in 1994 in the University of Oviedo, Spain. Afterwards, he did a Research Master in Turbomachinery in 1995 in the von Karman Institute, Brussels, Belgium. Finally, he obtained his PhD Degree in the Universidad de Oviedo, in 2000. He is currently an Associate Professor at the University of Oviedo (since 2002). His teaching experience covers a set of 23 Academic Years, since 1996-1997, with a total of 5000 teaching hours, covering the main Lecture topics of his field, Fluid Mechanics, Fluid Machinery and Fluid Installations. He has been the supervisor of 3 PhD candidates and more than 20 Final Degree and Master Thesis. His research activities cover a range of Fluid Mechanics and Turbomachinery applications, with an experience of more than 20 Journal papers and over 50 Conference contributions. Additionally, from 2010 to 2014, he was sub-Director of the Polytechnic School of Engineering of Gijón with more than 6000 undergraduate students, 500 master students and 80 doctoral candidates.

Eduardo Blanco Marigorta is a professor of Fluid Mechanics in the University of Oviedo (Spain). His subjects include Fluid Mechanics, Hydraulic Power and Fluid Machinery. He has been teaching graduate and post graduate courses since 1994. His research interests are (among others) the numerical and experimental analysis of fluid machinery, and the biological flows in the lungs. He has written more than 50 international articles. He is the Coordinator of the Fluid Dynamics Engineering Research Group (GIFD) of the University of Oviedo.