AN INTERACTIVE VIRTUAL APPROACH AIMED AT ENHANCING THE ACHIEVEMENT OF LEARNING OBJECTIVES IN TURBOMACHINERY SUBJECTS

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Abstract

In this work, we propose a methodology to improve the achievement of learning objectives in turbomachinery courses. This methodology is based on a series of exercises to be solved by students during the course that address the main learning objectives of the subject. We present the results of applying this methodology in two consecutive academic years. In one of these years, the exercises were optional and did not contribute to the final course grade; in the other year, the average grade on the exercises accounted for 5% of the final course grade. We show that proper completion of these exercises improves both the course's success rate and the students final grades.

Keywords: Problem-based learning, Engineering, Online learning platform.

1 INTRODUCTION

Hydraulic turbomachinery is a mandatory subject in several engineering courses. Unlike other engineering subjects, it is based on a relatively simple conceptual framework and does not require advanced mathematical knowledge for problem-solving. Historically, these factors have contributed to a high success rate in this subject, perpetuating the use of traditional passive teaching methods to conduct these courses. However, in recent years, the success rate has gradually decreased. Students are finding it increasingly difficult to solve the problems of the subject. In particular, these difficulties arise when there are problems with many sections and require combining knowledge and methodologies from different chapters of the subject or mathematical methods (e.g., derivatives or trigonometry) that they have seen in previous courses.

In response to this challenge, and according to the current tendencies in active learning methodologies [1,2], we offer students a series of virtual exercises designed to help them explore in an autonomous way the methodological and conceptual aspects that are frequently challenging in problem-solving [3]. We have included these exercises in the Moodle learning platform of the University of Malaga, which is routinely used by the students in most of their courses. This allows students to gradually familiarise themselves with these aspects before applying them to more practical problem scenarios, including those posed in the subjects' more practical problem situations (such as those in exams).

In this study, we explore the effectiveness of this approach and its influence on student success rates and grades, assessing the results two years after its introduction. We will examine two distinct scenarios: firstly, the academic year 2021-2022, during which exercise grades were not included into the final course grade, and secondly, the academic year 2022-2023, where they constituted 5% of the final course grade. Additionally, we will discuss adjustments we intend to implement in the upcoming course to further enhance the exercises' impact on the students' performance.

2 METHODOLOGY

In this section, we describe the methodology of the study. We first discuss the structure and design of the exercises. Then, we show the data we gather from the online learning platform and how we analyse it.

2.1 Description of the exercises

The methodology has been applied to a course on turbomachinery from the Industrial Organisation Engineering degree. During the academic year, three exercises related to the main learning objectives of the course were conducted: turbomachinery design (first exercise) and hydraulic networks (second and third exercises). The results from two academic years (2021-22 and 2022-23) have been

analysed. In both years, the exercises were presented as voluntary activities. However, whereas in the initial year, the exercise grades served merely as a means for students to assess their own progress informally, in the subsequent year, the exercise grades constituted 5% of the final course grade.

The exercises were implemented in the Moodle learning platform of the University of Malaga, which students frequently use in most courses. Each exercise comprises five multiple-choice questions, each offering approximately seven possible answers (see Figure 1). In these questions, students have to solve a concise problem related to a fundamental concept from the learning objectives. While each question is designed to be solved in around 10 minutes, students are given 15 minutes per question, allowing a total of 90 minutes for completing the whole exercise. Students are permitted an unlimited number of attempts to complete each exercise, with the final attempt determining their grade.

P1. (10±2min) A centrifugal pump with no pre-rotation turns at 1700 r.p.m. with a volumetric efficiency of $\eta_{VOL} = 0.97$. The rotor has an exit diameter (d_2) of 50 cm, a width (l_2) of 2 cm, and an angle $\beta_{2a} = 25^o$. If the Pfleiderer coefficient is $C_H = 1$, obtain the theoretical suction height as a function of the flow rate, $H_t = f(Q)$, the maximum theoretical flow rate, Q_{MAX}, and the flow rate that maximises the theoretical power $Q_{W_{tMAX}}$.

- a) $H_t = 202.12 + 319.59Q$, $Q_{MAX} = 0.32m^3/s$, $Q_{W_{tMAX}} = 0.16m^3/s$
- b) $H_t = 202.12 + 319.59Q$, $Q_{MAX} = 0.63m^3/s$, $Q_{W_{tMAX}} = 0.316m^3/s$
- c) $H_t = 20.21 + 31.95Q$, $Q_{MAX} = 0.32m^3/s$, $Q_{W_{tMAX}} = 0.16m^3/s$
- d) $H_t = 202.12 - 319.59Q$, $Q_{MAX} = 0.63m^3/s$, $Q_{W_{tMAX}} = 0.316m^3/s$
- e) $H_t = 202.12 - 319.59Q$, $Q_{MAX} = 0.32m^3/s$, $Q_{W_{tMAX}} = 0.16m^3/s$
- f) $H_t = 404.24 + 639.18Q$, $Q_{MAX} = 0.63m^3/s$, $Q_{W_{tMAX}} = 0.316m^3/s$
- g) None of the above

Figure 1. Example of a question from a turbomachinery design exercise.

2.2 Available data

To analyse the effectiveness of the exercises in the learning process, we have used the following data:

1. Results from the exercises, including the grades, the number of attempts made, and the time spent on each attempt.
2. Grades from the exams. It is important to highlight that each of the problems presented to the students in the exam corresponds to one of the learning objectives addressed in the exercises.

2.3 Data analysis

To analyse the effect of the exercises on the global performance of the students, we study the correlation between students who pass the exercises and those who ultimately pass the exam. In both cases, passing is defined as when a student receives a grade of five or higher on a ten-point scale. For this analysis, students can be categorised into four different groups:

A) Students who pass the exercises and the exam.
B) Students who fail the exercises but pass the exam.
C) Students who pass the exercises but fail the exam.
D) Students who fail both the exercises and the exam.

Students who have not taken any of the official course exams have not been considered in this analysis, as it is assumed that they have dropped the course. It is also worth noting that groups B and D include students who have not even attempted the exercises (they have a grade of zero).

In virtual activities, it is common to encounter students attempting to cheat in order to achieve the highest possible grade with minimal effort. Two of the most common ways to deceive the system are:

1. Obtaining correct answers from a fellow student.
2. Exploiting the fact that they have unlimited attempts in exercises to arrive at the correct solution through a trial-and-error process.

These behaviours can often be identified by analysing the response patterns exhibited by the students. For instance, students who have only one attempt, with a very short duration (less than two or three minutes), usually correspond to cases where the student already possesses the correct answers and simply inputs them into the online platform. On the other hand, students with multiple short-duration attempts are generally associated with instances where the solution is achieved through trial and error. It's worth noting that, upon completing the exercise, the system displays the correct and incorrect responses to students, making it relatively easy to adjust answers until reaching the maximum score.

Below, we present the outcomes of our analysis when including all students and when filtering out students displaying irregular response patterns. We then compare the two scenarios.

3 RESULTS

We first present the results from the academic year 2021/22, where the exercise grades did not contribute to the final course grade. Then, we present the results from the academic year 2022/23, where exercise grades represent a 5% of the final course grade.

3.1 Academic year 2021/22

3.1.1 Raw data (including students with irregular response patterns)

Figure 2a shows the distribution of students for each group described in section 2.3. It is worth noting the low success rate of the subject in this academic year, as only 36% of the students were able to pass the exam. It is observed that 25% of the students who passed the exam also passed the exercises (group A), whereas only 11% of the students were able to pass the exam without having passed the exercises (group B). The most surprising result of this analysis is that the percentage of students who fail the exam having passed the exercises (group C) is nearly the same as the percentage of students in group A. Based on this observation, it seems unclear whether or not the exercises have a positive impact on the students' performance. Finally, students who fail both exam and exercises are the majority group (group D), with 40% of the students who took at least one exam in this academic year. If only students who fail the exam are considered, 63% of the students also failed the exercises, whereas 37% of them had passed the exercises before. While correlation between failing both exercises and exam was expected and it is thus not surprising to see a large percentage here, the percentage of students in group C is surprising and deserves further examination.

3.1.2 Filtered data (excluding students with irregular response patterns)

After filtering out the data of students exhibiting irregular response patterns, the statistics drastically change. We noticed an exceptionally high number of anomalous cases among students who passed the exercises and failed the exam (group C). More specifically, we observed that most of the students in this group presented a long series of short attempts, consistent with a resolution of the problem based on trial and error. In Figure 3a, we show the filtered distribution of students who passed both the exercises and the exam compared with those who passed the exercises but failed the exam. In this case, the balance between these groups is 71% versus 29%, compared with the distribution of 51% versus 49% before filtering out the anomalous cases.

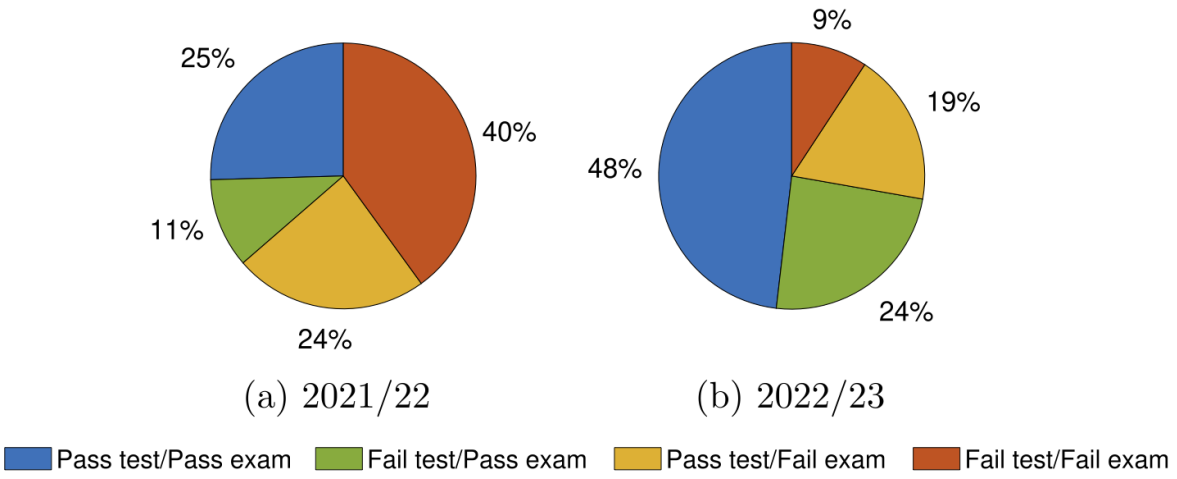

Figure 2. Statistics of students depending on their results on tests and exams. Results for two academic years: (a) 2021/22, tests not considered in the final grade, (b) 2022/23, tests accounted for 5% of the final grade.

3.1.3 Grades from students that passed the course

In Table 1, we show the grades of students who passed the exam, comparing those who passed the exercises (group A) with those who did not (group B). We observe that students who pass the exam without passing the exercises do not reach high grades. In particular, the average grade of this group of students is 5.5/10, while students who have also passed the tests had an average of 7.2/10.

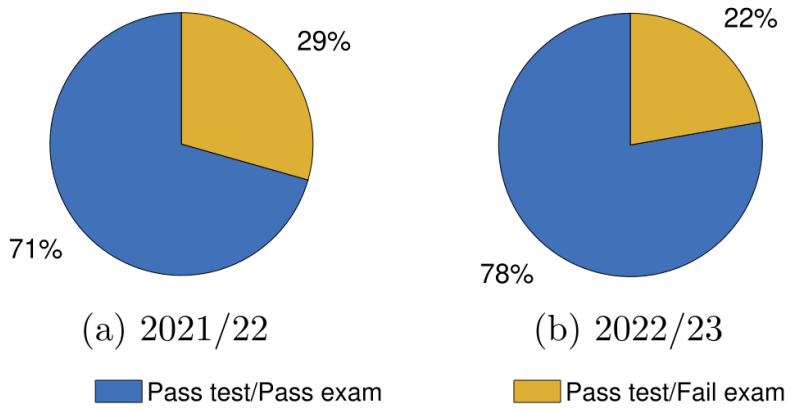

Figure 3. Balance between students who pass the tests and the course and those who pass the tests and fail the course. Results for two academic years: (a) 2021/22, tests not considered in the final grade, (b) 2022/23, tests accounted for 5% of the final grade.

3.2 Academic year 2022/23

Given the voluntary nature of the exercises, many of the students of the 2021/22 academic year did not perform the exercises or did not take them seriously. To increase the participation and focus of the students on the exercises, in the 2022/23 academic year, they were included in the course evaluation, accounting for 5% of the final course grade.

3.2.1 Raw data (including irregular response patterns)

The first significant difference that can be observed compared to the previous year is the increase in success rate. While in the previous academic year, only 36% of students who attended the exam finally passed, this percentage increased to 72% in the 2022/23 academic year. On the other hand, almost half of the students now pass both the exercises and the exam, compared to the 25% of the previous year (see Figure 2). At the same time, the students who fail the exercises and the exams

have been drastically reduced. These changes can be a direct consequence of factoring the exercises into the final course grade, which motivates students to obtain a good grade on the exercises. Finally, a slight decrease is also seen among students who pass the exercises and fail the exam.

3.2.2 Filtered data (excluding irregular response patterns)

After filtering out the anomalous patterns, we observe again that many of these cases correspond to students who pass the exercises and fail the exam. However, in this academic year, there is also a considerable number of students who pass the exercises and the exam with anomalous behaviour. This is a notable change compared to the previous year (46% of the total in group A compared to 16% in the previous year). A possible explanation is that the exercise questions were the same in both years and some students could have had the answers previously. Similarly to the previous year (see Figure 3), the balance between students who pass the exercises and the exam and those who fail the exam having passed the exercises is 78% versus 22%.

Table 1. Number of students in a certain range of grades for a given academic year and group: students who pass the exercises and the exam (A) and students who fail the exercises and pass the exam (B). Right column: averaged grade for each group of students and academic year.

Academic year	*5/10 - 7/10*	*7/10 - 8.5/10*	*8.5/10 - 10/10*	*Averaged grade*
2021/22 (A)	3	5	6	7.2
2021/22 (B)	6	0	0	5.5
2022/23 (A)	2	13	11	7.1
2022/23 (B)	13	0	0	5.9

3.2.3 Grades from students that passed the course

Table 1 shows the grades of students who passed the exam, comparing those who passed the exercises (group A) with those who did not (group B). In this case, we observe a similar behaviour to the previous year: students who passed the exam without passing the exercises have lower grades than those who passed the exercises. In particular, the average grade of students who passed the exam without passing the exercises is 5.9/10, compared with an average of 7.1/10 for those who passed the exercises before.

4 CONCLUSIONS

In conclusion, the methodology introduced in the last two academic years positively affects students' learning process. This effect can be seen in the large percentage of students who pass the exam having passed the exercises, as well as comparing the grades of these students with those who pass the exam without having passed the exercises. On the other hand, it has been observed that a large number of students exhibit irregular response patterns, and it has been necessary to eliminate these cases to obtain meaningful results. Factoring the exercise grades into the final course grade has increased the participation of the students in the exercises. However, it has also increased the number of anomalous response patterns. This could be attributed to the fact that the exercises were not modified with respect to the previous year, and some students could have step-by-step resolutions of the exercises. To prevent students from cheating in their responses, we plan to introduce several changes in the upcoming course: first, we will introduce a reasonable limit in the number of attempts, second, the exercise questions will be modified with respect to those of previous years, and third, the numerical values that appear in each problem will be customised depending on the national identification number of each student. With these steps, we intend to address this issue and encourage students to put forth extra effort to complete the tasks.

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