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# A Remedial Course in Moodle for Undergraduate Classes of Circuit Theory

Paolo Manfredi, *Senior Member, IEEE*, and Enrico Perano

***Abstract*—E-learning courses and tools have increased their importance and have been adopted by a growing number of universities, mainly due to the unfortunate occurrence of the COVID-19 pandemic. This work presents an asynchronous and online remedial course implemented in Moodle to assist students enrolled in undergraduate engineering classes of electrical circuit theory. The course is organized in weekly modules that are delivered in parallel to regular classes. Each module consists of a preliminary test to ascertain the student's preparation on the topic and learning units whose access is restricted to students who fail the preliminary test. The approach is suitable for large classes and is aimed to avoid students' procrastination and promote additional and constant practice throughout the course, thereby eventually improving also their performance at the final examination as well as their preparation for subsequent courses involving the same topics. Two experiments conducted in consecutive academic years, involving 407 and 379 students, are discussed. The exam performance of students who attended the remedial classes, even those with low initial performance, was significantly better compared to those who did not participate at all. Additionally, the correlation with past exam scores demonstrates that students who engage with the Moodle course show substantial improvements in their exam scores.**

***Index Terms*—Circuit theory, e-learning, Moodle, remedial course.**

## I. Introduction

AT PRESENT, e-learning courses have increased their importance and have been adopted by a growing number of Italian universities, mainly due to the unfortunate occurrence of the COVID-19 pandemic [1]. In addition to the obvious use of videoconferencing systems, which are essential for delivering remote lessons, new digital learning tools and methodologies have been used to encourage students' participation and interaction [2], [3], [4]. Research activities on the design of online courses, teaching methodologies, and the assessment in digital learning environments are undergoing a marked increase that is expected to continue even now that the pandemic is over.

Online learning in engineering education has been already adopted in the past [5], [6]. Particularly during the COVID-19 pandemic, the number of online courses was relevant [7]. After the pandemic, the experience of online courses moved to remedial courses [8] or courses for special needs in support of classical teaching with lessons in classrooms [9], [10], [11]. In addition, online education showed positive effects on students' satisfaction and learning outcomes [12] and has become a preferred learning mode for many graduate students [13].

Politecnico di Torino is one of the major technical universities in Italy, with over 35'000 students enrolled. Since the occurrence of COVID-19, the university adopted Moodle for on-line examinations. After the pandemic was over, Moodle became a widely adopted tool that is still used for in-class examinations, but also for other teaching activities throughout the course. At the Law faculty of the University of Turin, Moodle and other e-learning tools are used to deliver personalized remedial classes aimed at supporting on-time graduation [14]. Moreover, the abundant data collected with on-line courses is also being increasingly used to predict students' career and identify students at the risk of dropping out [15], [16], [17], [18], [19].

It is known that many university students tend to postpone their study until the last days before the finals [20]. The main reasons for their procrastination can be summed up in low motivation, the lack of time management, peer pressure, fear of disapproval and failure, and dishonest personality [4], [21], [22], [23], [24], [25]. The disapproval may be from their classmates, their professors, or even from themselves, especially if they aim to achieve a very good performance. Indeed, procrastinators often fear other people's judgment, and for this reason they believe they must complete the job at their best because of the fear of being judged negatively, thus focusing excessively on performance. As a result, they put a lot of pressure on themselves, which can cause depression, anxiety, and low self-esteem (e.g., [26] and references therein).

Overall, procrastination reduces the learning efficiency and increases the chances to accumulate deficient skills during the course [27], [28]. Moreover, it was shown to increase academic misconduct [29]. Indeed, especially in engineering classes, developing deficient skills since the very beginning of the course jeopardizes the effective learning of more advanced topics. Since the causes of failure and the learning needs of failing students are mostly individual, the ideal intervention should be a one-to-one tutoring involving a personalized learning program [30]. As this approach is not always affordable, an alternative solution can be a program

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that adapts as much as possible to the individual needs of the students and is mainly delivered via e-learning tools [31]. The remedial course must address most failure causes and allow the participants to practice and monitor their improvements. On the other hand, the participants must focus only on the items that are strictly needed to compensate for their lack of knowledge, pacing the activity according to their improvements.

Addressing academic procrastination and underachievement is a rather recent topic in educational research. Most intervention approaches that are found in the literature are of psychological nature and focus, e.g., on the cognitive aspects or students' self-esteem, self-efficacy, and time management [32], [33]. Similarly, the review in [34] discusses that most literature approaches are of therapeutic nature, relying either on treatment or prevention. Nonetheless, it also reports some simple and effective methods that involve the instructor's intervention. For instance, it was found that weekly graded spot quizzes motivate procrastinators to study continually [35]. Sequential and modular approaches were also found beneficial in reducing procrastination [36].

However, these approaches do not scale well to large classes. In this context, technology-assisted interventions appear to be still a rather unexplored field. The authors of [37] proposed the use of mobile text messages to send reminders to students with high procrastination and low performance levels. Similarly, e-mail alerts providing students with feedback on their progress were investigated in the study proposed in [38].

Motivated by the above scenario, this work describes a remedial course designed for undergraduate engineering classes of electrical circuit theory. The course is developed on the university Moodle platform and consists of weekly modules that are made available to students at the end of regular classes. Each module consists of a preliminary test that is used to ascertain the student's preparation on the specific subject. Students who fail the test are encouraged to follow remedial learning units consisting of brief recapitulatory videos and guided exercises. On the students' side, the goal is to stimulate students towards a constant study and practice by means of a continuous self-assessment, in order to improve their learning efficiency and their preparation for the final examination. These benefits positively reflect also on the lecturers' side, leading to an improved teaching experience and success rate at the final examination.

Since academic year 2021-22, the proposed remedial program is offered to undergraduate classes in the Biomedical Engineering program at Politecnico di Torino, Italy. Based on the students' performance at the examinations, it is shown that attending the remedial program has a remarkably positive impact on the final score. The improvement is even more visible among students who had already failed the class in previous years. The qualitative feedback expressed by the students in anonymous surveys also confirms that the project is highly appreciated. Although the program has been designed for classes of electrical circuit theory, the applicability naturally extends to many other scientific courses.

The study presented in this work makes several contributions:

- It describes a structured, technology-assisted intervention to tackle academic procrastination and underachievement, suitable for large classes;
- It provides a large-scale empirical evidence on the impact of a structured and adaptive remediation based on a learning management system in a core engineering course;
- It introduces and evaluates a conditional mechanism that enables self-assessment and ad-hoc intervention;
- It discusses and compares two complementary implementations, i.e., a quasi-experiment with voluntary enrollment and a full-cohort observational experiment across two consecutive years.

The remainder of the paper is organized as follows. Section II discusses the motivation and the implementation of the proposed remedial course. Section III outlines the adopted methodology. Sections IV and V discuss the results of the pilot quasi-experiment and the follow-up observational experiment, respectively. The results are summarized and discussed in Section VI. Finally, conclusions are drawn in Section VII.

## II. Motivation, Requirements and Goals of the Proposed Remedial Course

A remedial course is expected to address the dominant causes of students' failure. The causes of failure of college and university students have been studied in several works. An extensive analysis, providing a great deal of information on this problem, is found in [39]. In this analysis, about 2'500 college students who experienced failure were screened, and four root-causes of failure were identified:

- Individual students' abilities and efforts (74.2%);
- Individual students' abilities and efforts influenced by external factors (4.4%);
- Class learning materials, lessons, instructors, and school environment (10.2%);
- Other factors outside students' control (11.2%).

The first root-cause (i.e., "individual students' abilities and efforts") was largely dominant over the other root-causes and includes the following, more specific causes:

- Motivation (47%);
- Study habits (23%);
- Academic preparation (16%);
- Attitude (14%).

It is easy to figure out routes to failure triggered by lack of motivation, poor study habits and preparation, and inappropriate attitudes. As in other scientific courses, some of their peculiarities further exacerbate the incidence of motivation, study habits, preparation and attitude as causes of failure.

In circuit theory classes, many students tend to have a superficial approach or have a great difficulty due to the incremental structure, where every topic is a prerequisite for the next ones: any lack of compliance to the activity of the course is likely to jeopardize the benefits of course attendance. In addition, many topics require a solid mathematical background, which is not always available to students [40].

Unfortunately, a remedy is hardly possible for the attitudinal cause, as it has psychological roots and can be affected by life experiences only. Similarly, great efforts to improve motivation may sometimes provide marginal benefits. On the contrary, study habits and preparation can be effectively addressed by continuous monitoring and guidance of the student, implemented by e-assessment and intervention as needed [41]. Monitoring and guidance may have indirect benefits on motivation as well, since the student may experience gratification in improving his/her knowledge of the subject and in his/her ability to solve assigned problems. In conclusion, continuous monitoring and one-to-one intervention is a key tool to tackle individual students' abilities and efforts.

Therefore, in order to be effective for most failure causes, a remedial course must satisfy a reasonable set of specifications that are listed below:

- It must adapt to the specific needs of participants, who should focus only on the individual items that are strictly needed to amend their specific lack of knowledge.
- It must allow the participants to constantly practice and monitor their improvements.
- The participants' activity must pace according to their improvements and individual needs.

Eventually, the aim of our Moodle course is to provide students with a self-assessment tool for each topic of the regular course, enabling them to further explore areas where they have shown deficient skills.

## III. Methodology

This section describes the educational context, the design of the Moodle-based remedial intervention, the research design adopted, the study procedures, the measures collected, and the techniques applied to analyze data.

### A. Educational Context

The remedial program described in this work was specifically designed for the course of circuit theory in the Biomedical Engineering program at Politecnico di Torino, Italy. This is a 14-week, 8-credit[1] undergraduate course consisting of a total of 80 hours of lectures (60 hours of theory + 20 hours of practice sessions). The course is organized in 4.5 h/week of theoretical classes and 1.5 h/week of exercise practices. The typical number of enrolled students is about 400 per year, including the students who failed the exam in previous years. The students are split into two parallel classes.

The final exam is a written test consisting of:

- A quiz part on the Moodle platform involving six basic exercises, worth 2 points each, and two more advanced exercises, worth 4 points each, for a total of 20 points. For these problems, only the result is evaluated.
- One essay problem involving a combination of several topics, worth 10 points, for which the complete solution is assessed.

The total is 30 points, the maximum score according to the Italian grading system for university exams. However, instructors can award honors (*laude*) to students who achieve a perfect score and/or earn additional bonus points, such as those from home activities. The minimum score for passing the exam is 18.

For the presented analysis, it is important to mention that at Politecnico di Torino students can:

1) Attempt the exam up to four times during the academic year: twice at the end of the semester in which the course is delivered, once in the complementary semester, and once during the fall retake session;
2) Reject a passing grade if they are not satisfied with the result;
3) Retake the exam an unlimited number of times.

### B. Intervention: Remedial Course on Moodle

The remedial course has been implemented on the online teaching platform on the university website. It is divided into 14 sections: the first section, which is open to everyone, recapitulates some math fundamentals that are prerequisites for the course. The remaining thirteen sections are divided by topic, each corresponding roughly to one week of classes (cfr. Section III-A). For each topic, there are:

- A "check-in" test;
- A remedial lecture, whose accessibility is conditional on failing the check-in test;
- A "check-out" test, whose accessibility is conditional on completing the remedial lecture.

These items are described later in this section.

*1) Resources:* The remedial course is implemented using the Moodle platform [42], which was already integrated in the university website to handle online teaching and exams during the COVID-19 pandemic. A MATLAB-based service for the automated generation of circuit problems, named *autoCircuits*, is used to generate the questions for the tests in an XML format that is readily imported in Moodle. A public version of autoCircuits is available via web [43] for the students to practice with the course's topics. Animated educational videos for the remedial lessons are made in Canva [44], and additional exercises are taken from educational textbooks by one of the authors.

*2) Check-In Tests:* This tool is used for a preliminary assessment of the student's preparation on the specific subject. The test consists of problems by all means similar to the ones appearing in the quiz part of the final examination and are mostly generated with autoCircuits [43]. These problems are mainly of numerical (or cloze) and multiple choice type, the latter with a penalty for wrong answers. An example is shown in Fig. 1. The typical number of problems varies from 6 to 8 and the time available to the student ranges from 30 to 60 minutes, depending on their difficulty and the number of questions. The score for passing the test is set between 60% and 80%, depending on the difficulty of the topic. Indeed, for more basic topics, such as the application of Kirchhoff's laws and the calculation of equivalent resistances, failing 40% of the problems cannot be considered as acceptable. The student can attempt the check-in test only once. Passing the check-in tests indicates that the student is sufficiently knowledgeable on the topic, so no other action is needed. Failing the check-in

[1]According to the European Credit Transfer and Accumulation System (ETCS).

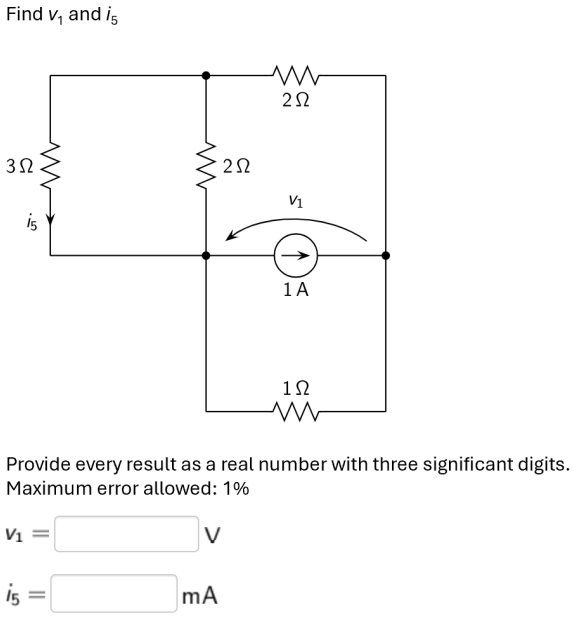



Fig. 1. Example of question in the check-in test (translated from Italian). The problem asks to calculate voltage $v_1$ and current $i_5$ in a resistive circuit containing a single current source.

test requires instead that the student attend the corresponding remedial learning unit. The results of the check-in and check-out tests are also used for grading purposes, as will be described later, in Section III-D.

*3) Remedial Lectures:* The remedial lectures consist of a combination of the following:

- Videoclips presenting the basic theoretical notions on the topic and the guided solution of some exercises. The total duration is typically between 20 and 40 min;
- Slides from the videoclips;
- Extra slides with additional exercises;
- A set of quizzes with basic, medium, and advanced difficulty.

To successfully complete the lesson, students must reach the end by correctly solving all exercises. Moreover, they must spend a minimum amount of time that is calculated based on the duration of the videoclips and the estimated time required to solve the problems. This is implemented in order to discourage the student from skipping the videos and answering randomly to the questions.

Hence, the students are given the opportunity to recover the topic using the videoclips, to practice with additional exercises, and to assess their learning and performance on a number of further problems with growing difficulty. According to mistakes in the answers, the students are recommended going back to the lecture covering the corresponding topic.

*4) Check-Out Tests:* The check-out test is formally equivalent to the check-in test. The access is conditional upon completing the lecture, which is tracked using the "activity completion" feature in Moodle. The test is meant as a self-assessment about whether the deficient skills on the subject

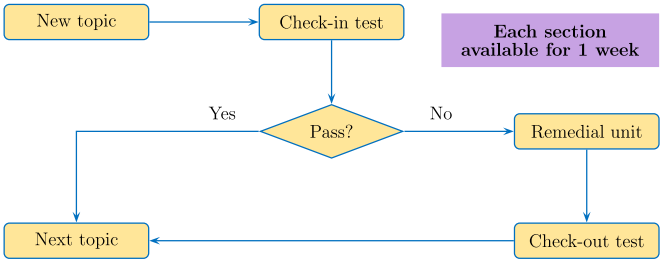



Fig. 2. Block diagram summarizing the weekly organization of the remedial course.

have been recovered or not. The structure, i.e., the type of questions, number of exercises, and available time, are the same as for the check-in test. Failing the check-out only represents a warning for the student that the deficient skills on the corresponding subject have not been recovered, but it does not preclude the access to the subsequent sections.

*5) Weekly Organization:* Figure 2 illustrates the weekly organization of the remedial course. Each section is made available immediately after the corresponding topic is covered in the regular classes, and for one week only. This means that the student has one week to attempt the check-in test and possibly follow the remedial lectures. In this way, students can take advantage of the unit and carry out the tasks in an asynchronous way, whenever they find it more convenient. At the same time, they are required to complete the section in a limited time frame, to keep up with regular classes and avoid the possible accumulation of deficient skills that may prevent the correct understanding of subsequent topics. It is also important to mention that each section is made available individually and unconditionally. Skipping a section does not preclude the fruition of the following sections, although it is highly discouraged.

*6) Alignment With Final Exams:* It is useful to mention that the quiz problems in the final exam are by all means similar to the exercises in the check-in/check-out tests, whereas the essay problem is not specifically addressed by the remedial course. Indeed, the program is mainly aimed at covering basic skills and individual topics, rather than addressing the solution of more complex problems.

### C. Research Design

The analysis presented in this work concerns two separate studies. The first pilot study foresaw a voluntary enrollment in the remedial program and concerned 407 students overall, of which 330 were first-time attendees and 77 were repeating students (42 with prior exam attempts). The follow-up study concerned 379 students, all of which had access to the intervention.

*1) Pilot Study: Quasi-Experiment With Voluntary Enrollment:* A pilot version of the remedial program was launched in academic year 2021-22. In this preliminary experiment, the enrollment was carried out on a voluntary basis at the beginning of the course. The aim was to form two groups of students: a control group who attended only the regular

in-person classes and a test group who also followed the remedial course, so that the performance of the two groups could be compared at the end of the semester. For a fair assessment of the efficacy, we targeted to enroll at most 2/3 of the students.

Out of 407 students enrolled in the regular course, 185 (45%) eventually enrolled in the remedial course. Among them, 34 students (8% of the total) had previously attended the course, and 20 of these had attempted the exam at least once but did not pass. The remaining 222 students, who did not enroll in the project, formed the control group. It should be noted that, since the program was offered in the framework of a regular curricular course, any enrollment procedure other than a voluntary one would have created an unacceptable discrepancy in the teaching experience and would have been therefore unfair.

Table I summarizes the enrollment status and exam performance for students who had previously attempted the exam. Notably, the different group combinations appear to be fairly homogeneous:

- 151 out of 330 first-time students enrolled in the Moodle course (46%);
- 34 out of 77 students with prior enrollment joined the Moodle course (44%);

Moreover, among the 77 students with prior enrollment, 42 (55%) had previously taken the exam. The average exam score is slightly higher for the students who did *not* enroll in the Moodle class, while the average number of attempts is similar between the two groups.

*2) Follow-Up Study: Full-Cohort Observational Experiment:* Following the success of the pilot version, the remedial program was offered again in the following academic year, i.e., 2022-23, and made available to all students. The number of students enrolled in the regular classes was 379. In order to assess the impact and efficacy of the program, the analysis was carried out by clustering the students into four groups, based on the activity rate in the remedial course. The pie chart in Fig. 3 summarizes their participation to the remedial course, measured by the number of completed modules. A module is considered complete if the check-in test has been passed or the check-out test has been attempted, indicating that the corresponding remedial lecture was also completed. The students were clustered into four groups, identified with the same color labeling as in Fig. 3:

- Cluster A (green) for the group with activity between 10 and 13 modules;
- Cluster B (blue) with activity between 7 and 9 modules;
- Cluster C (yellow) with activity between 4 and 6 modules;
- Cluster D (red) with activity between 0 and 3 modules.

Approximately 37% of the students belonged to cluster A, having completed 10 or more sections, while a substantial portion (about 43%) attempted fewer than four sections, thus belonging to cluster D.

The complementary nature of these two study designs—one with a test/control structure and one with an engagement-based clustering—improves the robustness of the evaluation and allows drawing different insights.

### D. Procedures

As a further motivation for students to participate to the remedial course, a bonus was granted based on test results and added on top of the final examination score.

In the pilot study, up to 4 extra points were granted as a reward for participating in the Moodle course and provided a motivation for participating. Yet, the students could still obtain the highest grade without participating in it. For grading purposes, three attempts were allowed for check-out tests, whereas the check-in test remained limited to one attempt only. For each section, the student could earn the following scores:

- Full score (100%) by passing the check-in test;
- Two-thirds of the score (67%) by passing the check-out test on the 1st attempt;
- One-third of the score (33%) by passing the check-out test on the 2nd or 3rd attempt;

No points were granted when failing both the check-in and check-out tests. It was decided to give a higher score to students who passed the check-in test in order to discourage them from deliberately failing, driven by the curiosity to access the remedial material. The final bonus was computed proportionally, based on the scores of the 13 individual sections.

To encourage the participation in the follow-up study, the remedial course was considered as an integral part of the examination, with up to 3 points on the final grade granted based on the remedial course performance. This means that it was no longer possible for the students to achieve a grade with honors without taking part in the remedial program. Furthermore, the grading system was simplified compared to the pilot edition. Only one attempt was allowed also for the check-out tests. A full score (100%) was granted for passing the check-in test and a half score (50%) was granted for passing the check-out test, again with no score given for failing both tests. This means the student earned 0.231 points for each passed check-in test and 0.115 points for passing a check-out test, for a maximum total of 3 points for passing all the 13 check-in tests, a target that was achieved by 2 students only.

### E. Measures and Instruments

The effectiveness of the remedial course is assessed both quantitatively, based on the scores at the final examination, and qualitatively, based on anonymous surveys at the end of the course. As measures of the learning performance, we consider both the remedial course score and the exam score. The former is on a 0–4 scale in the 2021-22 pilot study and on a 0–3 scale in the 2022-23 follow-up study. For the exam score, we consider both the quiz score (0–20) and the problem score (0–10) separately, as well as the aggregate exam score (0–30). We remind that the threshold for passing the exam is 18/30. We also track the historical performance through the average scores of previous exam attempts for students retaking the exam. Moreover, we consider the number of completed modules as a measure of the engagement in the remedial course.

In the pilot study, we investigate the difference in the distributions of the exam scores between the test and control groups. We also assess the correlation between exam scores

and Moodle performance and, for students with prior exam attempts, the correlation between current and past exam scores. Moreover, we analyze the responses to an anonymous survey that was delivered at the end of the study to collect data about the perceived usefulness, workload, and difficulty of the remedial course.

In the follow-up study, we assess the performance of the four clusters based on the distribution of the final exam scores. Furthermore, we investigate the correlation between exam results and remedial course scores or past exam scores. Although we did not deliver a dedicated survey in this case, we could still collect some useful feedback from the generic anonymous survey that the university provides to the students at the end of each course.

### F. Data Analysis Methods

To analyze the impact of the intervention, the distributions of the exam scores are investigated both qualitatively, using histograms, box plots, or violin plots, and quantitatively, based on descriptive statistics such as mean, standard deviation, and skewness. Moreover, the effect size is determined based on Cohen's $d$ and the performance across groups is compared using Mann-Whitney tests. The correlation between exam and Moodle scores is assessed based on the Pearson correlation coefficient, while we use Wilcoxon signed-rank tests to determine the significance of the difference between current and past exam scores. It should be noted that non-parametric tests are appropriate due to the differences in group size and the non-normal distributions involved.

### G. Ethical Considerations

According to the ethics committee of Politecnico di Torino, ethical review and approval were waived for these studies because the subject aligns with the institutional mission of innovative teaching, which is promoted and validated by the university.

## IV. Results: 2021-22 Pilot Study

### A. Quantitative Results–First Final

In this section, we analyze the performance of the students at the first final examination. We compare the score distributions of the various groups. Moreover, we correlate the exam score with the remedial course score and, for students with prior exam attempts, to the average score of past exams.

Three students who enrolled in the remedial course but did not performed any module were considered as "outliers" and excluded from the analysis. Hence, the analysis concerns 253 students, out of which 141 followed the remedial program and 112 did not.

*1) Analysis of Exam Scores:* The performance of the students in the first final examination session is illustrated in Fig. 4. The left and central panels show the distribution of the scores obtained in the quiz part (maximum: 20) and in the essay problem (maximum: 10), respectively, whereas the right panel shows the distribution of the total combined score (maximum: 30). Green and red bars denote the group

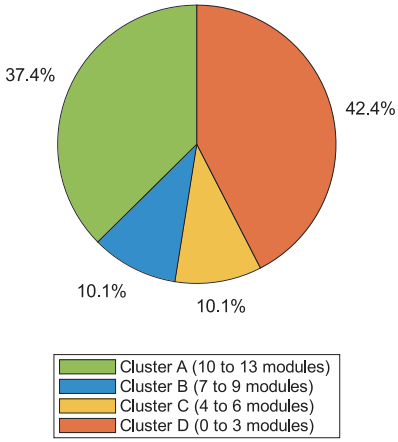



Fig. 3. Pie chart illustrating the student's participation to the remedial course, based on the number of attempted check-in tests.

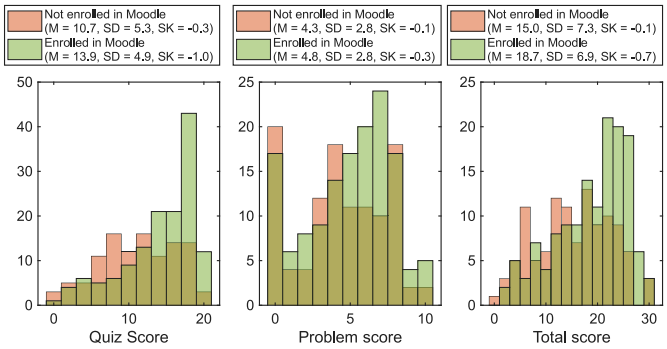



Fig. 4. Histograms comparing the performance at the first exam session between students who attended (green bars) and did not attend (red bars) the remedial program. The mean, standard deviation, and skewness of the distribution are indicated in the legends.

of students who followed and did not follow the remedial program, respectively. Of course, these scores do not include the possible bonus earned through the remedial course.

It is observed that the distribution of the green population is asymmetric and shifted towards the highest grades compared to the red distribution, which is instead rather symmetric and Gaussian-like. Indeed, as noted in the legends, the average quiz score of the students who did attend the remedial program is 13.9, compared to 10.7 for the students who did not enroll in it. Furthermore, the standard deviation is slightly lower for the green population, indicating that the distribution is less dispersive (i.e., more consistent). Finally, it is relevant to note that the skewness is negative and larger in magnitude for the green population, meaning that the distribution is left-skewed and the results are concentrated around the highest scores. The skewness is instead close to zero for the students who have not followed the remedial program.

A better performance of the green population is observed also for the score distribution of the essay problem, with an increment of 0.5 points in the average score, similar dispersion, and again a more pronounced asymmetry towards the highest scores. However, the benefit of the remedial course is less evident in this case since, as already noted, the remedial lessons mainly address the skills required by the quiz part.

TABLE I
SUMMARY OF MOODLE ENROLLMENT STATUS

| First-time enrolled in regular course | Enrolled in Moodle | Already taken exam | Size | Average # exam attempts | Average exam score |
|---|---|---|---|---|---|
| Y | Y | n/a | 151 | n/a | n/a |
| Y | N | n/a | 179 | n/a | n/a |
| N | Y | Y | 20 | 2.25 | 6.00 / 30 |
| N | Y | N | 14 | n/a | n/a |
| N | N | Y | 22 | 2.50 | 7.17 / 30 |
| N | N | N | 21 | n/a | n/a |

TABLE II
COMPARISON BETWEEN THE EXAM PERFORMANCE (TOTAL SCORE) OF STUDENTS ENROLLED AND NOT ENROLLED IN MOODLE. THE ANALYSIS IS REPEATED FOR SUBGROUPS OF STUDENTS: FIRST-TIME ENROLLEES IN THE REGULAR COURSE, PAST STUDENTS, AND STUDENTS RETAKING THE EXAM

| | Enrolled in Moodle | | | | Not enrolled in Moodle | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Population | Size | M | SD | SK | Size | M | SD | SK | Cohen's $d$ | Mann-Whitney $p$-value |
| All students | 141 | 18.73 | 6.93 | -0.71 | 112 | 14.95 | 7.34 | -0.11 | 0.53 | <0.001 |
| First-time students | 120 | 19.26 | 6.76 | -0.86 | 104 | 15.41 | 7.26 | -0.20 | 0.55 | <0.001 |
| Past students | 21 | 15.70 | 7.25 | -0.02 | 8 | 9.03 | 6.00 | 1.18 | 0.93 | 0.030 |
| Students with prior exams | 13 | 14.83 | 7.74 | 0.00 | 4 | 8.94 | 8.63 | 1.08 | 0.70 | 0.234 |

Nevertheless, an improvement is also established for the problem part. The advantage provided by the remedial course is also reflected into the total cumulative score, with an average that is overall 3.7 points higher for the green population.

This analysis was aggregated for first-time enrollees and students retaking the exam, revealing a positive correlation between exam performance and participation in the Moodle course. However, more motivated students are likely more inclined to join the remedial course, making it difficult to distinguish whether the observed correlation reflects greater self-motivation or the actual benefits of the Moodle course. Hence, in Table II the analysis of the total exam score is repeated for different groups of students, which allows us to make further interesting considerations:

1) The average score is higher for first-time enrollees. This is expected, as the group includes top students who are likely to pass the exam with high scores on their first attempt. Nevertheless, the average score is more than 3.8 points higher for the students enrolled in the Moodle course.
2) Among past students, the benefit of the remedial course is even more evident, with an average score that is 6.7 points higher.
3) A similar result is observed by restricting the analysis to past students who had already attempted the exam without passing, with a difference of 5.9 points.

For all cases considered, Cohen's $d$ suggests a medium to large effect of the remedial course [45]. The Mann-Whitney test supports a significant difference between the score distribution of students enrolled or not enrolled in Moodle, except for students with previous exam attempts, likely due to the small group size. Overall, although we cannot definitely claim that the remedial course was beneficial, the results for past students who struggled with the topic indicate that it is likely beneficial.

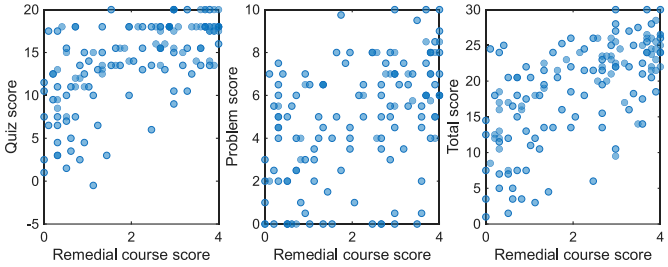



Fig. 5. Correlation between the scores obtained at the first final examination (y-axis) and in the remedial course (x-axis).

*2) Correlation With Moodle Performance:* Among the students enrolled in the Moodle course, we further compared the performance between those students who performed six modules or less (32) and seven modules or more (109). The results are summarized in Table III and further corroborate the conclusion that the participating in the Moodle course is helpful.

So far, we only considered the participation in the remedial course, without taking into account the performance in the Moodle tests. The scatter plots in Fig. 5 show the correlation between the examination scores and the remedial course score (maximum: 4). It is observed that students with a high score in the remedial course tend to achieve a high score also in the final exam, especially in the quiz part (left panel). Indeed, this population exhibits a Pearson correlation coefficient of $r = 0.65$, which indicates a large effect of the remedial course. The result is reflected also in the total score (right panel, $r = 0.64$), whereas the correlation coefficient for the problem part is $r = 0.46$.

TABLE III
ANALYSIS OF EXAMINATION SCORES FOR STUDENTS WITH HIGH AND LOW ACTIVITY IN THE MOODLE COURSE

| | Seven modules or more | | | | Six modules or less | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Population | Size | M | SD | SK | Size | M | SD | SK | Cohen's $d$ | Mann-Whitney $p$-value |
| Students enrolled in Moodle | 109 | 20.7 | 5.8 | -1.07 | 32 | 12.11 | 6.34 | 0.18 | 1.43 | <0.001 |

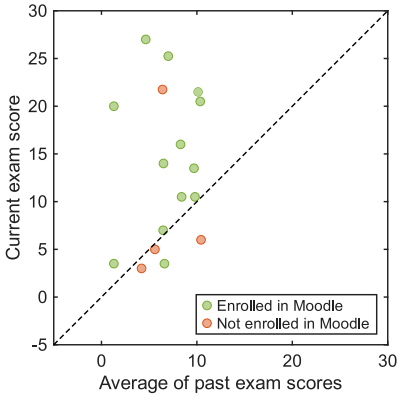



Fig. 6. Correlation between the average of past exam scores (x-axis) and the score at the first final examination (y-axis).

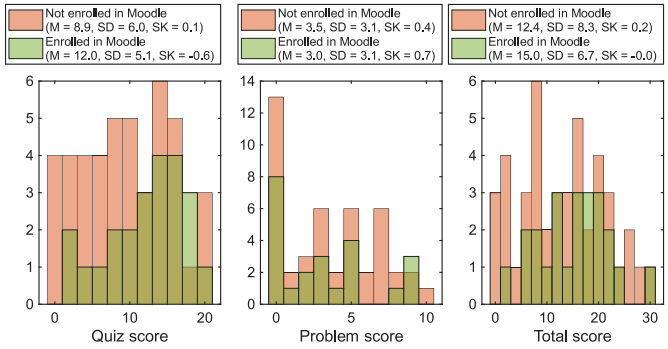



Fig. 7. Comparison of the score distributions at the second exam session of students who did not attend the first session.

As noted before, the correlation is more evident in the quiz part, since it was more similar to the remedial course tests. In particular, it is remarkable that no points are found in bottom-right corner of the quiz plot, meaning that there were no students who achieved a high score in the remedial course and a low score in the exam quiz. Conversely, we find students with low Moodle score but high quiz score, suggesting that the participation is beneficial regardless of the performance.

*3) Correlation With Past Exam Scores:* The scatter plot in Fig. 6 shows the correlation between the current exam score and the average score from previous exams for students with prior attempts. The green and red circles indicate students enrolled and not enrolled in Moodle, respectively. The dashed black line is the bisector: points above it refer to students who obtained a higher score compared to their previous attempts. It is interesting to note that all students enrolled in Moodle, except one, achieved a higher score. Conversely, three out of the four students not enrolled in Moodle obtained a lower score. The Wilcoxon test yields a $p$-value of 0.002 when comparing current and past scores for students enrolled in Moodle, and a $p$-value of 0.875 for students not enrolled, supporting the conclusion that they are significantly different only for the former.

### B. Quantitative Results–Second Final

We now repeat the analysis for the second exam session. In this case, four students enrolled in Moodle were removed from the analysis due to their inactivity. Hence, the analysis regards 175 students, of which 64 were enrolled in Moodle and 111 were not.

We recall that students are allowed to take the exam twice and can reject a positive evaluation from the previous session. Out of the 64 students enrolled in Moodle, 23 took the exam for the first time, while 41 had already attempted the exam in the first session. Similarly, 45 students not enrolled in Moodle took the exam for the first time, while 66 had already attempted it in the first session. The above distinction is important because performance on the second attempt is typically better.

*1) Analysis of Exam Scores:* Figure 7 shows the score distributions at the second final examination, limited to the students who did not take the exam in the first session. The conclusions of the previous test case are confirmed for the quiz part, with the students who joined the remedial course achieving in average a score that is 3.1 points higher. Compared to the red population, the lower dispersion and the shift towards the highest grades of the green population are again confirmed by the lower standard deviation and by a skewness that is negative and higher in magnitude, respectively. However, for this second test case, no particular benefit is observed for the essay problem, with the green population achieving an average score that is slightly lower.

Table IV summarizes the results and focuses the analysis also on different subgroups. In this case, we also distinguish between the students who also took the exam in the first final and failed or rejected the grade, and those who only attempted the exam in the second final. As expected, the average score is higher for the students who attempted the exam twice. However, while there is no significant difference between first-time students enrolled or not enrolled in Moodle, the difference in average score is remarkable for past students. The effect is also confirmed by Cohen's $d$, while the Mann-Whitney test tends to reject the hypothesis due to the low sample size.

*2) Correlation With Past Exam Scores:* As before, the correlation analysis between current and past exams score suggests that the remedial course is beneficial. As shown in Fig. 8, all the eight students with past exam experience achieved a better score at the second final. Conversely, five

TABLE IV
COMPARISON BETWEEN THE EXAM PERFORMANCE (TOTAL SCORE) OF STUDENTS ENROLLED AND NOT ENROLLED IN MOODLE. THE ANALYSIS IS REPEATED FOR SUBGROUPS OF STUDENTS: FIRST-TIME ENROLLEES IN THE REGULAR COURSE, PAST STUDENTS, AND STUDENTS RETAKING THE EXAM

| | | Enrolled in Moodle | | | | Not enrolled in Moodle | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Population | First session | Size | M | SD | SK | Size | M | SD | SK | Cohen's $d$ | Mann-Whitney $p$-value |
| All students | N | 23 | 15.00 | 6.69 | -0.04 | 45 | 12.38 | 8.33 | 0.18 | 0.33 | 0.206 |
| | Y | 41 | 20.17 | 6.10 | -1.38 | 66 | 19.98 | 7.66 | -0.67 | 0.03 | 0.631 |
| First-time students | N | 19 | 15.00 | 6.90 | 0.045 | 31 | 14.47 | 8.22 | -0.15 | 0.07 | 0.912 |
| | Y | 32 | 19.31 | 6.31 | -1.35 | 59 | 20.61 | 7.34 | -0.81 | -0.18 | 0.173 |
| Past students | N | 4 | 15.00 | 6.48 | -0.69 | 14 | 7.75 | 6.74 | 0.89 | 1.03 | 0.125 |
| | Y | 9 | 23.22 | 4.27 | -0.72 | 7 | 14.68 | 8.85 | 0.37 | 1.22 | 0.078 |
| Students with past exams | N | 3 | 15.00 | 7.94 | -0.60 | 8 | 9.19 | 8.03 | 0.57 | 0.66 | 0.472 |
| | Y | 5 | 23.10 | 4.16 | -0.43 | 3 | 11.42 | 6.50 | 0.05 | 2.00 | 0.071 |

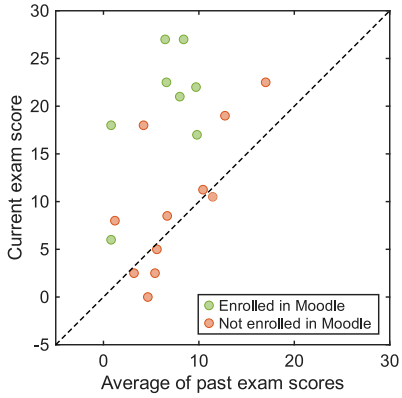



Fig. 8. Correlation between the average of past exam scores (x-axis) and the score at the second final examination (y-axis).

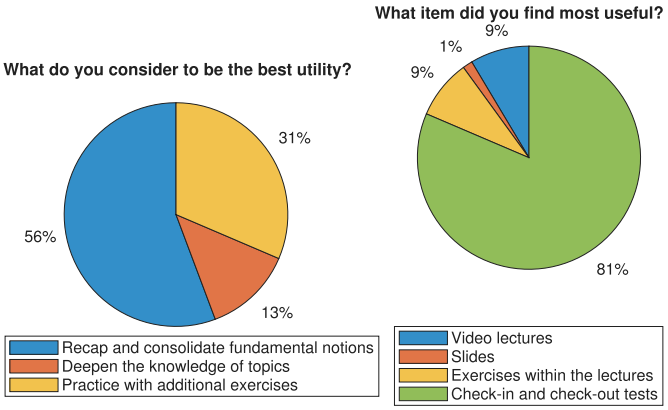



Fig. 9. Pie charts illustrating the perceived usefulness of the remedial course.

students out of the 11 not enrolled in Moodle obtained a lower score. The Wilcoxon test suggests the score difference for the group enrolled in Moodle is significant with a $p$-value of 0.008, while it is not significant for the group of students not enrolled in Moodle, for which it yields a $p$-value of 0.278.

### C. Qualitative Feedback

The effectiveness of the remedial course is further corroborated by the analysis of the students' feedback collected through an anonymous survey delivered at the end of the program, in which the participants were asked to rate the remedial course on the whole. A number of 70 responses were collected.

Figure 9 provides two pie charts indicating the perceived usefulness of the program. Specifically, 55.7% of the students found that the main benefit was the recapitulation and consolidation of the fundamental theoretical notions, followed by the opportunity to practice with additional exercises (12.9%). However, 81.4% of the participants appreciated the check-in and check-out tests the most.

Furthermore, most of the students (75.7%) found the overall workload acceptable, and a similar percentage (71.4%) found the difficulty of the tests reasonable. The remaining students found the tests hard, with no student finding them easy. Finally, the vast majority of the students (94.3%) found the remedial course useful, with a 24.3% indicating that it even exceeded their expectations.

The analysis of the students' opinions on the perceived quality of the remedial course and the superior performance achieved in the final examinations allows concluding that the pilot experiment was highly effective and successful.

## V. RESULTS: 2022-23 FOLLOW-UP STUDY

### A. Quantitative Results

This section discusses the quantitative results based on the students' performance at the final examination. Since this time the remedial program was offered to all students, it is no longer possible to sharply distinguish between students who did follow and did not follow it. Rather, the performance is correlated to the fruition of the remedial program according to the clusters indicated in Fig. 3.

*1) Analysis of Score Distribution:* Figure 10 provides the score distributions at the two final examination sessions. The superposition of violin and box plots allows appreciating both the shape and the median of the distribution. The left and right panels show the quiz and total score, respectively, while the top and bottom panels refer to the first and second exam

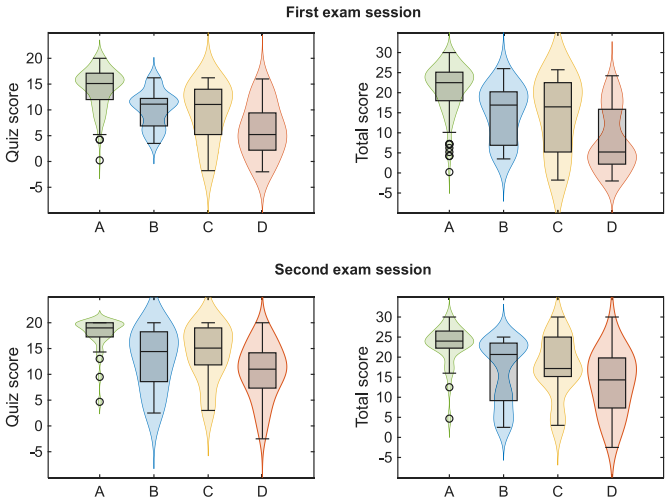



Fig. 10. Distribution of the final examination scores for the four clusters of students with different levels of activity in the remedial program.

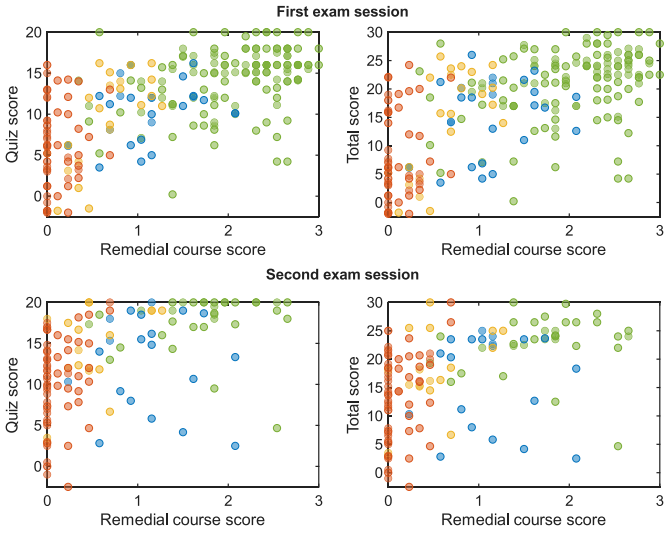



Fig. 11. Correlation between the scores obtained at the final examination (y-axis) and in the remedial course (x-axis) for the four clusters of students.

session, respectively. It is observed that the distribution shifts towards the highest scores as the participation rate is increased. In particular, an asymmetry towards the top is once again observed for clusters A and B, the ones with the highest activity in the remedial program.

*2) Correlation With Moodle Performance:* To further investigate this aspect, Fig. 11 shows the scatter plots highlighting the correlation between the examination scores and the remedial course score. This visual comparison allows observing a striking result. While it is obvious that red (cluster D) and yellow (cluster C) points have a low score in the remedial course, as they refer to those students who attempted a little amount of tests, and hence lie on the left side, it is also observed that they are concentrated in the lower part of the graph, indicating a low score also in the examination. On the contrary, the vast majority of green points (cluster A) lie in the upper part of the scatter plot. As was also observed in Fig. 5, very few green points lie in the bottom-right corner,

TABLE V

COMPARISON ON THE EXAM PERFORMANCE OF STUDENTS WITH LOW SCORES IN THE MOODLE COURSE

| Exam session | Cluster | Size | M | SD | SK |
|---|---|---|---|---|---|
| 1 | A | 5 | 16.99 | 9.31 | -0.13 |
| | B | 6 | 10.90 | 6.74 | 0.40 |
| | C | 14 | 11.01 | 9.84 | 0.17 |
| | D | 53 | 7.87 | 7.71 | 0.60 |
| 2 | A | 3 | 19.78 | 4.02 | 0.20 |
| | B | 5 | 15.60 | 8.73 | -0.62 |
| | C | 15 | 16.12 | 7.59 | -0.13 |
| | D | 59 | 13.53 | 7.58 | -0.25 |

TABLE VI

AGGREGATE ANALYSIS OF AVERAGE EXAMINATION SCORES OVER THE ENTIRE ACADEMIC YEAR

| Cluster | Size | Exam part | M | SD | SK |
|---|---|---|---|---|---|
| A | 139 | Quiz | 15.40 | 2.81 | -0.50 |
| | | Total | 22.42 | 4.31 | -0.47 |
| B | 36 | Quiz | 12.05 | 3.55 | -0.24 |
| | | Total | 17.07 | 5.60 | -0.81 |
| C | 33 | Quiz | 12.06 | 4.90 | -0.64 |
| | | Total | 16.80 | 7.29 | -0.60 |
| D | 93 | Quiz | 9.15 | 4.78 | -0.50 |
| | | Total | 12.22 | 6.97 | -0.24 |

indicating a positive correlation between the remedial course and the examination performances.

Now, let us restrict the comparison to students with a Moodle score below 0.75. This condition inherently defines clusters D and C (e.g., the maximum achievable Moodle score for cluster D, with three modules or fewer, is 0.692), and corresponds to students who did not fully engage with the remedial program. For clusters A and B, it identifies students who failed most of the tests, indicating lower skills, despite having followed most of the remedial units. The results, summarized in Table V, confirm that even the least-skilled students, despite poor Moodle performance, achieved significantly higher marks in the examinations. Specifically, the average score difference between clusters A and D was 9.12 points in the first exam session (Cohen's $d$ = 1.15) and 6.25 points the second exam session (Cohen's $d$ = 0.82).

*3) Aggregate Analysis Over the Entire Academic Year:* Table VI shows the results of the aggregate analysis over the entire academic year, i.e., also including the third (summer) and fourth (fall) examination sessions. For the students who attempted the exam more than once, we consider the average scores. It is noted that the average scores increase consistently with the activity rate in the remedial program.

Table VII presents the pairwise Cohen's $d$ coefficients between clusters, along with the results of the Bonferroni-corrected Mann-Whitney tests. Both measures show little difference between clusters B and C, which have moderate

TABLE VII
PAIRWISE COHEN'S $d$ AND BONFERRONI-CORRECTED MANN-WHITNEY TESTS BETWEEN CLUSTERS

| | Cohen's $d$ | | | Mann-Whitney $p$-value | | |
|---|---|---|---|---|---|---|
| | B | C | D | B | C | D |
| A | 1.16 | 1.12 | 1.84 | 0.000 | 0.000 | 0.000 |
| B | | 0.04 | 0.73 | | 1.000 | 0.002 |
| C | | | 0.65 | | | 0.011 |

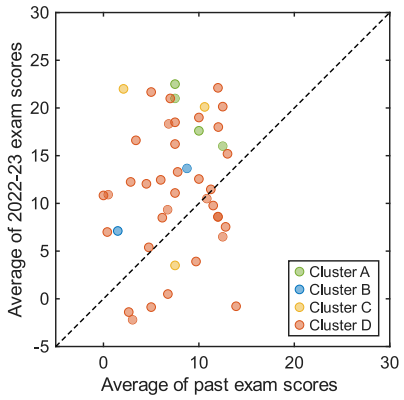



Fig. 12. Correlation between the average past exam scores (x-axis) and the average exam scores of current year (y-axis).

Moodle activity. In contrast, the differences between these clusters and clusters A and D are significant, with effect sizes consistently increasing as the Moodle activity rate rises.

*4) Correlation With Past Exam Scores:* In the scatter plot of Fig. 12, we analyze with the correlation between the average current-year exam scores and the average past exam scores for the students who had already taken the exam in the past. There are only four students with past exam attempts who belong the cluster A (i.e., they performed 10 modules or more) and two belonging to cluster B. All these students achieved a higher grade in 2022-23. Of the three students belonging to cluster C, two achieved a higher grade. Finally, of the 36 students belonging to cluster D, 12 obtained a worse grade.

### B. Qualitative Feedback

In this second experiment, no specific survey concerning the remedial course was delivered to the students. However, some students provided a positive feedback about the remedial program in the anonymous questionnaire that the university makes available and invites to submit at the end of each regular course. The most relevant comments and suggestions are reported below (translated from Italian):

- "I wanted to recommend that you continue the weekly test in future courses as well, as I found it extremely useful for keeping up with the course."
- "The idea of using Moodle is very good, both for the advantage it provides in preparing for the exam and for the motivation it gives to keep up with the explanations and topics, making it easier not to lose track."
- "I believe the Moodle remedial course is a great help in preparing for the exam."
- "The weekly Moodle activities are very effective, as they allow for continuous learning of the subject."
- "The weekly Moodle exercises were extremely useful, allowing the topics to be gradually reinforced in a secure way, ensuring a much more solid preparation for the exam–at least for me."
- "The weekly quizzes were useful for studying consistently, but the fact that they were two weeks behind the syllabus meant that in class, we were never fully up to date with the topics and always a bit behind in reviewing them."
- "The remedial course was useful, but due to the way the schedule was organized, the tests sometimes covered topics explained more than a week earlier, making it a bit difficult to keep up with the new theoretical lessons."

It is important to note that the last two comments highlight an inherent limitation. The remedial sections can only be offered after the topic has been fully covered in class. Since each section corresponds to one week of lessons and remains available for one week, it is inevitable that students may complete the remedial unit approximately two weeks after the topic was first introduced in class.

## VI. DISCUSSION, LIMITATIONS, AND FUTURE WORK

The proposed remedial course tackles procrastination and underachievement by introducing structured weekly modules and self-assessment tests. The conditional access to remedial lectures and check-out tests enable ad-hoc intervention and accountability of the student behavior.

The efficacy of the remedial course was assessed over two academic years. In the first deployment (2021-22), the course was available only to students who voluntarily enrolled at the beginning of the semester. This allowed us to compare the distribution of exam scores between those who participated in the course and those who did not. In the following academic year, the Moodle course was made available to all students, enabling an analysis based on activity levels within the platform. Additionally, exam scores were correlated with performance in Moodle tests and, for students retaking the exam, with their past exam scores.

In all cases, students enrolled in Moodle or those with high engagement showed a significant effect. While this may reflect better attitudes, skills, or higher self-motivation, the correlation between Moodle performance and past exam scores suggests that the remedial course also benefits less-skilled students and those who struggled in previous years. Notably, students with low performance but high Moodle activity achieved significantly higher exam scores than those with low Moodle activity, with effect sizes from medium to large based on Cohen's $d$. We can therefore conclude that engagement intensity positively correlates with improvement, even among low-performing students.

A limitation of our analysis is that performance in the circuit theory course was not correlated with students' overall self-motivation and academic abilities, such as their GPA or other private data typically not available to us due to privacy regulations. Although obtaining such personal data

is challenging, future work will aim to incorporate a more rigorous analysis considering these factors.

Another limitation of this study is that self-regulated learning (SRL), which plays a crucial role in students' ability to engage with online courses, was not directly measured. While certain engagement behaviors in Moodle, such as test completion rates and activity patterns, may serve as indirect indicators of SRL, a more rigorous assessment would be needed to explicitly evaluate students' self-regulation strategies. Future work could incorporate these measures to better understand how SRL influences the effectiveness of the remedial course.

Regarding activity rates, an analysis of attempted tests reveals a steady drop-off from the initial to the final modules. This suggests that students tend to disengage suddenly, rather than participating intermittently. While this could reflect the increasing complexity of the material in the regular classes, there is potential for implementing measures to sustain engagement throughout the semester. To address this, we plan to introduce gamification into the remedial course, offering badges and rewards consistently, rather than relying solely on a bonus score at the final examination.

Furthermore, the analysis of Moodle data to identify patterns and predict students' performance in advance, with the goal of issuing potential warnings, is currently underway as part of a thesis project.

## VII. Conclusion

This article described an online remedial course that has been created as a support to undergraduate courses of circuit theory at Politecnico di Torino, Italy. The need for this remedial course arose in the attempt to improve the performance of students who typically encounters difficulties with circuit theory, often ending up in failing the exam multiple times. The course was created using the Moodle platform and is not limited to a mere repetition or review of the topics that are covered in the regular classes, but it also allows the students to recognize and fill their own gaps, deepen the subjects, and advance independently.

The remedial course is made of weekly modules that cover the topics of one week of classes. Each module features a preliminary test (check-in) based on which the student can ascertain his/her level of preparation. If the test is failed, the student gains access to a remedial unit consisting of new didactic video clips and further exercises of increasing difficulty. Upon following the learning unit, the student can re-attempt the test (check-out) to verify his/her progress on the topic. The remedial course is synchronous with in-class lectures, since each module is made available only once the corresponding topic has been fully covered. However, the student can take advantage of it asynchronously during the time frame of one week during which the module remains available.

The course was initially offered on an experimental level during academic year 2021-22, with an enrollment on a voluntary basis. This allowed creating two separate test and control groups, based on which the effectiveness of the remedial program was investigated. The analysis showed a remarkable impact, with the students in the test group achieving significantly higher scores in the final exam, which a score distribution skewed towards higher grades.

Following success of the pilot experiment, the following academic year (2022-23) the remedial course was made available to all enrolled students. Despite the absence of distinct test and control groups in that case, it was still possible to assess the positive impact of the remedial course by correlating the exam performance to the rate of fruition. It was found that students who carried out most of the remedial units performed significantly better at the exam.

Hence, the two experiments were somewhat complementary and allowed collecting different insights. Furthermore, the students explicitly showed a large appreciation for the course, which is testified by their positive answers and comments in anonymous surveys.

All in all, the solution proved to be even more useful and advantageous, further motivating the students to follow the course with greater commitment and attention. Although this work provided empirical data on a specific learning intervention, we believe it offers interesting practical implications for universities using online remedial courses and educators designing similar support strategies. Moreover, it is important to note that, although the course is currently delivered weekly alongside regular classes, it can also be offered as a summer remedial course, where all modules are made available simultaneously for an extended period.

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