Learning Through Explanation: Producing and Peer-Reviewing Videos on Electric Circuits Problem Solving

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Abstract*—*Contributions: **This article presents the results from a teaching innovation project based on the creation of educational videos by students and their assessment through blind peer review in the context of an electric circuit course. This article also analyses the activity's impact on learning outcomes by comparing the results of participating students with nonparticipants, as well as with results from the previous years. The study includes surveys completed by students.**

Background: **Electric circuit courses involve a cumulative learning process that advances throughout the course. Students who do not adhere to a regular study-homework routine often struggle to maximize the benefits of their class time and are more prone to test failures.**

Research Questions (RQs): **RQ1) Can peer assessment be relied upon as a grading method in an electrical engineering course? RQ2) Is it possible to enhance students' study routines and improve their results by incorporating assessment activities different from partial exams, such as creating educational videos and peer review assessments?**

Methodology: **Students create videos, which are then submitted to the designated task through the Moodle workshop tool. Subsequently, peer reviews are conducted using a rubric form. The reliability of peer review is analysed by comparing the grades assigned by students with those assigned by teachers who are introduced as incognito reviewers.**

Findings: **The evaluation system, relying on peer assessments, demonstrated fair reliability. Participants have substantially improved their academic performance while dedicating less time to preparing for the different evaluation tests.**

***Index Terms*—Active learning, digital competence, educational technology, electrical engineering education, empowering students, motivation, peer assessment, presentation skills.**

I. Background and Significance

THE INTEGRATION of new digital tools provides educators with an opportunity to reimagine and enhance traditional teaching techniques and evaluation methodologies. The innovation project presented in this article aims to create a new teaching methodology for students of electric circuit courses by combining various educational strategies. This initiative is centered around four fundamental innovation pillars as follows.

1) *Learning by Teaching:* This pedagogical approach, also related to the flipped classroom active methodology, requires a deep understanding of the subject, and the practice has been identified as a beneficial strategy to enhance students' learning in [1], [2], and [3]. When students engage in this process, they are required to articulate their understanding in a clear and concise manner. This activity not only reinforces their own comprehension but also helps to identify gaps in their knowledge. Moreover, the act of creating teaching materials compels students to organize the information logically and present it in a way that is accessible to others.
2) Acquiring a deeper understanding of the complex and abstract ideas commonly present in science, technology, engineering, and mathematics (STEM) disciplines. The use of video-based learning has demonstrated having a positive impact on processing capacity thanks to the use of the dual channel for information transmission: a) verbal and b) pictorial. This has been deeply explained by the cognitive theory of multimedia learning (CTML), resulting in the achievement of deeper learning [4], [5].
3) *Enhancing the Evaluation and Feedback Mechanisms While Empowering Students Through Collaborative Learning:* Peer-review assessment offers the potential to impact the students' motivation, critical thinking, and overall academic performance in engineering courses [6], [7]. Through peer review-based activities, students have the opportunity of evaluating each other's work, providing constructive feedback, and engaging in meaningful discussions that deepen their understanding of electric circuits principles. Furthermore, revising solutions from other students will expose them to different views and approaches to understanding how to solve an electric circuit.
4) *Acquiring Digital Competence and Communication Skills:* By elaborating videos and being engaged in peer review, students can gain experience in conveying and discussing complex engineering concepts clearly. This will enhance their training for the demands of the industry helping to promote a successful transition from academia to professional practice. Digital competence and communication skills are imperative for future

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engineers, who will be expected to work in collaborative teams and articulate their ideas with precision [8], [9], [10], [11].

This work presents the outcomes of a teaching innovation project centered around the development of educational videos by students, with their evaluation conducted through a blind peer review process. Several authors have documented the various benefits of using video-based learning in STEM disciplines. Besides the above-mentioned benefits for conceptual learning as explained by the CTML, videos also have the potential to increase students' motivation, satisfaction, and academic performance [12], [13], [14], [15], [16]. Moreover, recent studies also demonstrate how electrical engineering didactic videos have the potential to enhance quality perception, performance, and interest in engineering education [17], [18].

Finally, the fact that developed video-materials can remain available for other students to be used as pedagogical aid is also contributing to mitigate one of the main challenges in the use of videos in formal education: the difficulties on finding suitable videos to fulfill specific academic needs. These challenges have been widely highlighted in literature both from the professor's perspective [19], [20], [21] and from the students' perspective for finding adequate videos for complementary self-directed learning [22]. The use of these videos in the proposed structured active learning environment might maximize their benefits.

A. Research Questions

As previously discussed, the use of peer-review assessment-based activities have been demonstrated to be beneficial for engineering courses [6], [7]. However, incorporating their assessment into the students' final grades is a more delicate matter, as it raises important considerations [23], [24]. This leads to the first research question (RQ) addressed in this study: RQ1) Can peer assessment be relied upon as a grading method in an electrical engineering course?

On the other hand, the advantages of using the learning by teaching methodology [1], [3], and video-based [12], [16] have been well demonstrated and discussed above. The importance of acquiring digital and communication skills is also evident [8]. In this context, the experiment conducted in this project encompasses all these pillars, leading to the second RQ addressed in this study: RQ2) Is it possible to enhance students' study routines and improve their results by incorporating assessment activities different from partial exams, such as creating educational videos and peer review assessments?

B. Electric Circuits Course

Courses covering the fundamentals and analysis of electric circuits are essential for all engineering disciplines. Circuit courses are typically integrated into the curriculum of the initial years of engineering bachelor programs. In the School of Engineering of Universidad Carlos III de Madrid (Spain), a first course on electric circuits is included in the second or third semester of various BSc programs under the title "Electrical Power Engineering Fundamentals (EPEFs)." This 14-week course, equivalent to six European credit transfer and accumulation system (ECTS) credits, is taken by around 500 students annually and is conducted by the academic staff of the Electrical Engineering Department. Part of the students take the course in Spanish, while the students who choose the bilingual modality of the course take it in English. For the English course, the main reference text is the book "Electric Circuits" by Nilsson and Riedel [25]. The course is divided into four main modules. The first module is introductory and reviews the main components of electrical circuits, the basic concepts of electromagnetism, and the laws for circuit analysis. The next two modules cover the analysis of circuits supplied in DC and AC. Students are instructed on the application of systematic methods of circuit analysis, such as mesh current and node voltage methods, Thévenin equivalent, and superposition. For AC circuits, the analysis is done in the frequency domain. The analysis of power in different systems is studied in depth, including concepts like active and reactive power and the physical meaning and relevance of the power factor. For three-phase systems, the analysis focuses on balanced systems. The application of the phase-neutral equivalent is introduced and applied to practical cases. Finally, concepts related to power in three-phase systems, such as reactive power compensation and power measurements in three-phase configurations, are included in this last part of the course. Additional teaching materials and planning are provided to the students through an open course ware (OCW) published by the authors of this work in [26].

The course is organized in sessions of two hours, including 13 theoretical sessions, 13 practice sessions, and three lab sessions. During the theoretical sessions, attended by groups of around 60–120 students, the professor explains the basics and theoretical concepts and solves examples on the board. In the practice sessions, students are split into smaller groups, typically comprising 30–35 students. This session involves the active participation of students, as the professor proposes exercises to be solved by the students using the knowledge already presented in the previous lectures of the course. Meanwhile, the professor assists various students in resolving the exercises, and the solutions are subsequently discussed on the board.

Additionally, the course includes three lab sessions conducted in groups of a maximum of 12 students throughout its duration. This hands-on experience enhances the practical skills of students, complementing their understanding of the theoretical concepts. The comprehensive approach adopted by the course is intended to ensure that students develop a well-rounded understanding of EPEFs.

C. Problem Definition

In electric circuits courses, owing to the intensive presence of abstract ideas and mathematical reasoning, it is crucial that students establish and adhere to a consistent regular study routine. Furthermore, the learning process is cumulative, building upon the knowledge acquired in prior lessons during each session and across the entire course duration.

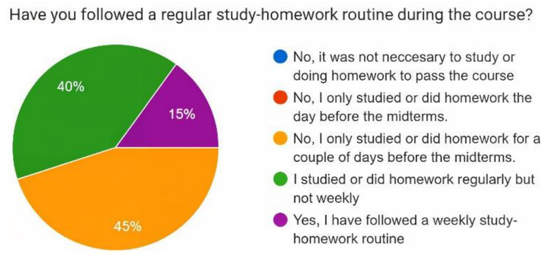

Fig. 1. Survey to collect feedback from students of the previous academic years. Question: Have you followed a regular study-homework routine during the course?

A frequent issue, particularly in the early stages of BSc studies, is that students deviate from the expected study routine, what may lead them to struggle on the resolution of the exercises proposed in class within a short span and in disengagement from the course. As a result, they often resort to the passive habit of copying solutions from the board, failing to engage actively, neither fully leveraging class time nor sustaining their motivation. These habits especially affect practical and lab sessions, significantly diminishing the overall effectiveness of the classes. Fig. 1 shows information on the study-homework routine of students of the previous courses (before the implementation of the innovation project), gathered from the answers of a survey filled by the students. It is remarkable that most students do not adhere to a consistent work routine outside of their class hours.

This loss of study routine begins to affect students from the second or third week of the course. From this point onward, many students struggle to tackle the exercises proposed by the professors in practical classes or comprehend the experiments in laboratories.

The lack of a specific understanding of the connections between different topics within the same subject, or between subjects, is also a contributing factor to such struggling, as students are not trained or familiar with cumulative learning. Instead, contents are commonly delivered and prepared in silos [27], [28] which constitutes one of the main reasons for the reduction in motivation and confidence, as well as academic stress and anxiety [29], [30]. These factors are closely related to the high dropout rates in engineering students and the decline in STEM vocations, also increased by distance learning [31], [32], [33].

In an attempt to enhance study habits, a system involving weekly assessment tests was explored in the previous courses by the authors of this article. However, weekly assessment tests were soon dismissed due to the escalation of students' stress levels and by the high workload that the management of the evaluation posed on the instructors. This is in line with the experience reported in [34]. The project presented in this article intends to continue exploring how alternative active learning methodologies might further contribute to the creation of such study habits within a sustainable approach.

D. Objectives of the Teaching Innovation Project

In the innovation project presented in this article, students are encouraged to create various educational videos explaining the problem-solving process of an assigned electric circuit. The videos will be evaluated by other students following a blind peer review process. The objectives of the project are outlined as follows.

1) Develop an educational methodology that promotes a regular and consistent study-work routine to maximize the effective utilization of classes and to enhance students' motivation and performance along the course while empowering them.
2) Conduct a comprehensive analysis to determine the reliability of students' peer evaluations. For that purpose, instructors will also be introduced as peers in the process, and a comparative analysis between the grades assigned by students and teachers will be elaborated.

To assess the impact of this innovative approach, the midterm grades of students in the course where the project is implemented will be compared with the results from the previous three courses. Additionally, the results from the annual teaching evaluations distributed to students will be analysed. Finally, a survey with specific questions about the project are distributed to the students participating in it.

E. Intended Outcomes

The elaboration of instructional videos will provide students with a deeper understanding of electric circuits concepts, while peer review assessments will offer them the opportunity to provide constructive feedback and engage in meaningful discussions, enhancing their comprehension of electric circuits principles. Additionally, reviewing solutions from fellow students exposes them to diverse perspectives and approaches, enriching their understanding of different ways of solving electric circuits. It is expected that this entire process will improve their understanding of electric circuits analysis and, consequently, increase their academic results in exams. In addition, they will gain experience in the digital and presentation skills necessary for success in the landscape of the engineering profession.

The various tasks required to be completed by students participating in this project will instill a regular study-work routine. This is expected to maximize their participation and utilization of classes, thereby reducing the total time of dedication needed to pass the course.

The present article presents the main results of the teaching innovation project, analysing its impact on the learning process and on the overall experience of the course. Finally, several recommendations and guidelines are provided to successfully implement an evaluation system based on students' peer review, drawing from the experience gained and results obtained.

II. System Design

A. General Description of the Proposed Activity

The course EPEFs is scheduled for 14 weeks and is divided into three modules: 1) basic concepts and DC circuit analysis (five weeks); 2) AC circuit analysis (five weeks); and 3) three-phase AC systems (four weeks). Project participants are required to create instructional videos solving designated

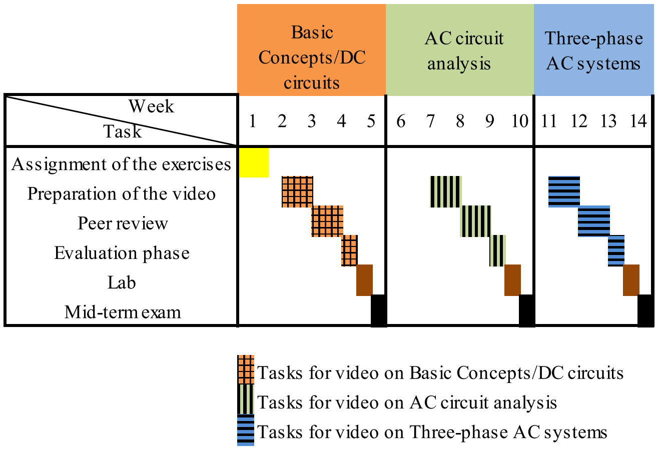

Fig. 2. Overview of the schedule of the different tasks within the course.

exercises for each of the three course modules. Each video should include the solution of a practical case along with a review of the theoretical aspects related to the problem.

As explained before, the created videos undergo assessment through a blind peer review process conducted in the virtual classroom of the course, which is a Moodle-based platform named Aula Global. Each video will be assigned to a minimum of three students who will be responsible for its evaluation and grading. Throughout the course, each student will be required to produce three videos (one for each module of the course) and to review nine videos from other students (three from each module of the course).

Fig. 2 provides an overview of the distribution of project tasks throughout the duration of the course, along with the midterm deadlines. This figure illustrates that the deadlines for different tasks have been proposed with the aim of maintaining a consistent work-load throughout the term, avoiding the common practice of concentrating efforts solely during the week leading up to the midterm exam, as depicted in Fig. 1.

The organization of the different tasks was managed using the Moodle activity workshop. Three workshop-type activities were created, one for every part of the course. Each workshop is divided into four different steps as follows.

Step 1 (Assignment): The various electric circuits to be solved throughout the course, along with their final numerical results, are provided to each student by the instructors at the beginning of the course. These assigned exercises resemble those discussed during the lectures. For this project, the exercises were selected from the exercise sheets published in the course "EPEFs" published by these authors on the OCW platform of the Universidad Carlos III de Madrid [26]. All exercises from these sheets have been distributed among the students to prevent them from having to solve the same exercise. If, due to the limited number of exercises, the same exercise must be assigned to multiple students, a specific method is designated for each student to ensure a distinct experience for everyone. This approach ensures that all content and methods taught throughout the course are covered. Additionally, since the exercises vary in difficulty, they have been grouped so that the overall level of difficulty of the three exercises assigned is balanced.

Step 2 (Preparation of the Video and Submission): Students are required to create a video demonstrating the comprehensive solution to the assigned circuit. This should include not only the proposed solution but also the methods and equations applied to obtain it. The instructions specify that the video explanations must cover the fundamental laws, equations, and principles applied during the problem-solving process. Students have the flexibility to choose the resources used for the creation of the video although project guidelines recommend options, such as using a tablet, blackboard, or a piece of paper to write the explanations. Subsequently, students are asked to produce an MP4 video that is didactic and easy to follow, tailored to the comprehension level of their peers in the course. It is mandatory for the video to feature the students' voice but not their image. Finally, the student must upload the video to the corresponding workshop task within the Moodle platform. The guidelines for preparing the video provided to students are available in Appendix B.

Step 3 (Peer Review Process): A minimum of three students participating in the project are designated as reviewers for each video. Each reviewer evaluates the video using a rubric form to ensure objectivity and consistency in the assessment. The rubric includes questions to assess three aspects: 1) content of the video; 2) quality of the video; and 3) engagement of the video. Furthermore, the submission of supplementary comments to justify the choices in the evaluation is mandatory. It is important to note that the peer review process is conducted anonymously for the student being assessed, but it is overseen by the course instructors. It is remarkable that students are aware that the quality of their reviews will also be a part of their final grade, so that unfair reviews may result in a grade penalty for students serving as evaluators. The guidelines for conducting peer reviews provided to students are available in Appendix B.

Step 4 (Evaluation Stage): The final task grade is calculated as the average of the grades provided by the different reviewers. In the rubric-based assessment, each criterion of the rubric form is assigned a specific weight: 50% for the content of the video, 25% for the quality, and 25% for the engagement. The final grade given by each reviewer is determined by the weighted sum of these criteria. In the innovation project that is reported in this article, the course instructors acted as additional reviewers to assess and compare the disparity between the grades assigned by students and those by the professors. The experience was used to evaluate the reliability of students' peer assessment as will be explained in further sections. The rubric for conducting peer assessments is available in Appendix A.

B. Implementation Using the Workshop Tool in Moodle 3

As mentioned before, the process described above was implemented using the workshop tool in Moodle, automating all project management tasks [35]. The workshop tool provides the flexibility to facilitate peer assessment and collaborative learning. It allows students to submit their work, such as assignments or projects, and engages them in reviewing their peers' submissions. Instructors can customize various parameters, including workshop type, number of submissions and reviews, and assessment criteria. The tool supports different submission formats, anonymous reviewing, and the setting of adaptive deadlines. It automates the calculation of final grades based on peer evaluations, considering the assigned weights for different criteria. Furthermore, students can provide feedback and comments during the review process, fostering a collaborative learning environment. Instructors can also act as moderators of the workshop, intervene if issues arise, and control the release of feedback.

The configuration of the workshop tool for this project has been found not so easy to accomplish. Professors involved in this project required support from the digital department of their university. In Section V, the applicability, and limitations of using the workshop tool are discussed.

C. Weight of the Project on Student Grading

Balancing student grades in projects is challenging; neglect can lead to disinterest, while excess creates stress and may lead students to engage in dishonest practices. To address this issue, the project grade does not determine the pass or fail status of a student in the course, which relies on the midterm and final exam grades, along with the completion of the project task. Successful completion of project assignments will significantly increase the final grade, contingent on passing the course exams. This approach aims to motivate students without overwhelming them with project-centric pressures.

III. Evaluation

The project has been implemented and evaluated in the course EPEFs, which is part of the BSc program in Robotics Engineering at Universidad Carlos III de Madrid. The project took place during the academic year 2022/2023, in a course comprising 32 students aged between 19 and 21 years. The sample consisted of the 29 students who participated in the project, including 13 men and 16 women. The GPA for the students in this course where the project has been implemented is 2.05, while the GPA for the same students considering all the courses for the corresponding academic year is 1.73. This group was chosen because its size was optimal for RQ1. To answer RQ1, it is necessary to view and evaluate all the videos in the same way the students do. If groups with a larger number of students had been selected, the time required for teachers to view and evaluate all the videos would be unmanageable. If it is demonstrated that peer assessment can be trusted in response to RQ1, the proposed project could be extended to groups with a larger number of students, eliminating the necessity to individually review every video created by each student. To strengthen the validity of the findings, a detailed analysis was conducted on both quantitative and qualitative results.

A. Quantitative Data Analysis

To address RQ1, which pertains to the reliability of peer evaluation by students, an in-depth analysis has been performed. This analysis considers the distribution of grades given in project tasks by the various peers. These grades have been assigned by the various peers, as well as by teachers introduced as incognito reviewers, who followed the common rubric provided in Appendix A. The disparity between the different grades assigned to the same video is analyzed. Subsequently, to analyse the reliability of peer assessment, the evaluations assigned by the students are compared with the grades assigned by the teacher to the video, using the same rubric form. The teacher, included as an incognito additional reviewer, provides an additional layer of assessment, ensuring a comprehensive and robust evaluation of each task.

Furthermore, in addressing RQ2, which examines the impact of the project on academic performance, the course's grade reports have been considered as a source of information. For this purpose, the distribution of grades obtained in the midterm exams and in the final grade of the course is compared to results from students in previous academic years before the project implementation. Three different control groups have been considered for this purpose, with a total population of 351 students distributed as follows: 50 for control group 1 (2021/2022), 187 for control group 2 (2020/2021), and 114 for control group 3 (2019/2020).

B. Qualitative Data Analysis

Complementary to the quantitative data, qualitative information has been collected to provide nuances about students' perception of the project's impact on their study routine and academic performance. For this purpose, three specific questions were addressed to the project's participants, with a five-point Likert scale type of response (from 1: totally disagree to 5: completely agree). The questions evaluated the project's impact on: maintaining a regular study routine during the course (Q1); obtaining a better grade in the course (Q2); and helping pass the course (Q3).

To assess the design of the project for implementation, it is important to evaluate aspects related to students' performance during the course and overall satisfaction of the students. Three questions about the course were elaborated and targeted at students from the academic course prior to the project's implementation (control group 1). The questions addressed: 1) class attendance and participation; 2) homework and study routines; and 3) time invested in midterm preparation and the perceived essentials for achieving success in the course. The same questions were replicated for students in the academic course in which the project was applied.

In the previous academic course, during the project planning stage, students were also consulted about the potential introductions of these activities and their willingness to participate in them. Finally, it is important to note that student anonymity is preserved in surveys for objectivity.

IV. Results

A. Project Impact on Student Work Routine and Feedback

This section analyses the project evaluation from students and its impact on their work routine using qualitative data collected from the distributed surveys.

Fig. 3 shows the answers in relation to the study-work routines of students participating in the project, as gathered from the survey. Results indicate that over 80% of students

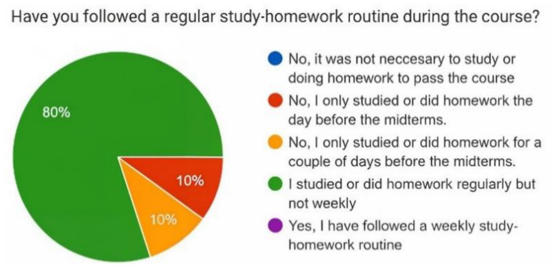

Fig. 3. Survey to collect feedback from students of the academic year in which the project is implemented. Question: Have you followed a regular study-homework routine during the course?

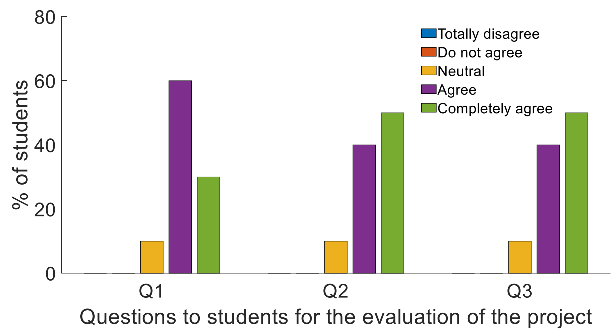

Fig. 4. Survey to collect feedback from students of the academic year in which the project is implemented (2022/2023). Questions: Do you think that the project is useful to: Q1-> Maintain a regular study routine during the course? Q2-> Obtain a better grade in the course? and Q3-> Help you pass the course?

follow a consistent study and homework routine, reflecting a significant increase compared to the results obtained before the project implementation, as shown in Fig. 1.

Fig. 4 provides a comprehensive overview of students' responses to various specific questions directly related to the project. Results show a highly positive student evaluation, recognizing the role of the project in fostering consistent study routines, improving grades, and contributing to their success in the course. It is remarkable the absence of negative responses, which highlights student satisfaction in the learning experience.

B. Impact of the Project on Academic Results

This section evaluates how the project has impacted the academic results of the students. An initial analysis compares the grades obtained in the midterms of students in the course in which the project was implemented and the grades obtained by students in previous courses. Fig. 5 shows the average scores for the three midterms that were taken during the course (DC, AC, and three-phase AC circuits) of students from four academic courses using a box-and-whisker plot. The grades exhibit an increase in the course when the project is implemented, with the median score situated close to 6.5 points, showcasing a notable improvement compared to the previous records. Notably, the scores achieved by students in the upper quartile, with the below limit close to 9 out of the maximum of 10 points, represent an impressive increase; this means that nearly 25% of students obtained an excellent grade (9–10 points according to the Spanish grading system).

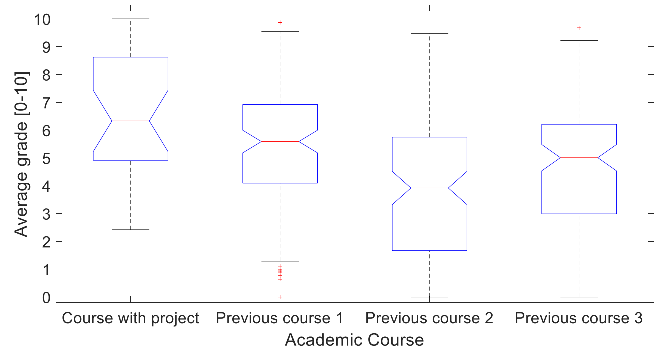

Fig. 5. Average student scores for the three mid-terms from the course in which the project implemented versus previous courses.

On the other hand, the 25th percentile has also increased, now hovering around 5 out of 10 points, aligning with the pass/fail threshold.

Fig. 6 represents the grades obtained in the project, calculated as the mean of the scores assigned by the various peers, against the grades obtained in the corresponding midterm for the three modules of the course for the students participating in the project. The correlations (ρ) between both variables have been calculated, and the linear regression has been plotted. It has been verified through Shapiro–Wilk tests that all the variables follow a non-normal distribution with a confidence level of 95%. Therefore, nonparametric statistical tests apply. For correlation analyses, Spearman's correlation tests have been applied.

From the results, there is a significant correlation (ρ) between the scores obtained in the video tasks and in the midterm exams for the three modules. This implies that students who perform well in the project also achieve good results in the corresponding midterm exams, and vice versa.

It can be seen that, as the course progresses, the correlation (ρ) between the variables becomes slightly weaker, particularly in the third and last module of the course. The AC circuits module ($p = 0.004$) presents a weaker correlation (ρ) than basic concepts/DC circuits ($p < 0.001$). Moreover, the three-phase AC circuits module ($p = 0.017$) presents the weakest correlation (ρ). This might be explained by the fact that many students tend to relax for the final midterm or become very busy with exams from others, making it challenging for them to maintain the same level of dedication to this particular course. On the one hand, some students had already achieved good results in the previous midterms, and they only needed to attain a minimum grade in the third midterms to pass the course. On the other hand, some students may have failed the previous midterms and subsequently given up on the course. However, in all cases the correlations (ρ) are significant for a confidence level of 95%.

Notably, less than 10% of students who successfully completed the tasks included in the project failed to pass the continuous evaluation of the course, and a mere fraction (less than 5%) did not successfully complete the course after the exam of the ordinary or extraordinary call. These results are remarkable compared to the number of students who did not

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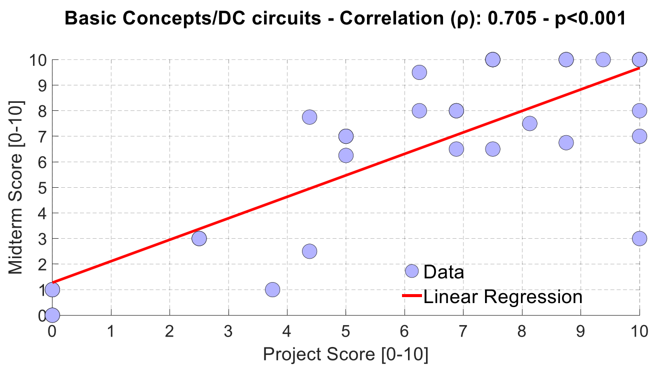
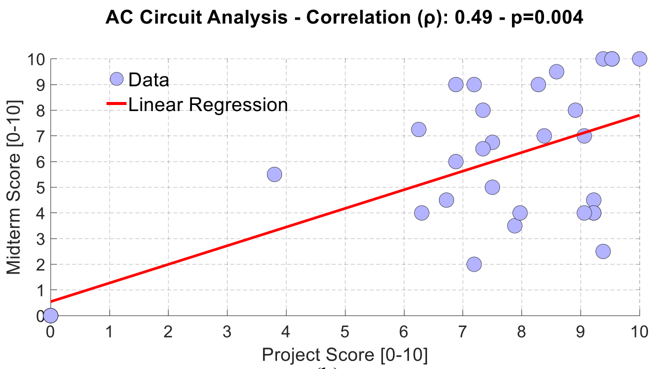


(a)



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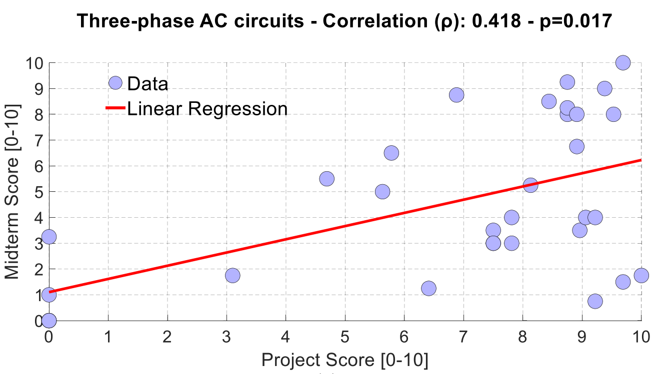
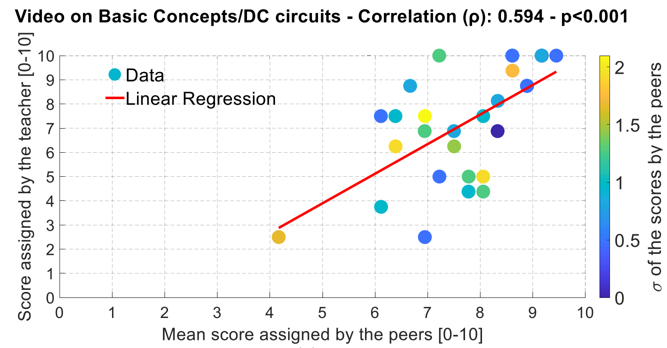


(c)

Fig. 6. Correlation (ρ) between the grades obtained in the projects, as provided by peers, and the grades in the corresponding midterm exams for the three modules of the course. (a) Basic concepts/DC circuits. (b) AC circuit analysis. (c) Three-phase AC systems. Spearman's correlation tests have been applied for the calculation in all cases.



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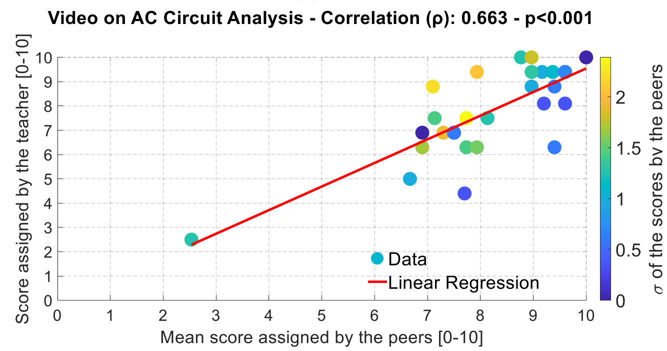

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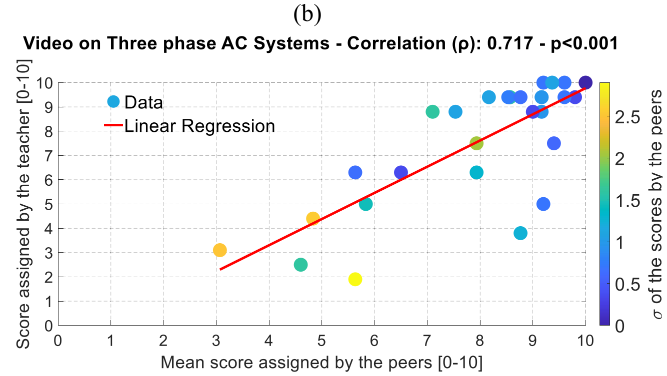

(c)

Fig. 7. Correlation (ρ) between the mean score assigned by the peers and the score assigned by the professor introduced as an incognito reviewer. The color bar measures the disparity between the grades assigned by different peers by calculating the standard deviation between them. Plots are represented for the three workshops of the course. (a) Basic concepts/DC circuits. (b) AC circuit analysis. (c) Three-phase AC systems. Spearman's correlation tests have been applied for the calculation in all cases.

pass the continuous evaluation in the previous courses, as shown in Fig. 5, or the past course failure rates, hovering around 20%.

C. Quality and Trust in Evaluation Based on Peer Review

This section analyses the accuracy of evaluations based on peer review by students, comparing them with those provided by the teachers of the course. Fig. 7 represents the grades provided by the peers, calculated as the mean of the scores assigned by the various students, against the grade assigned by the teacher, for the three modules of the course. The correlation (ρ) between both variables was calculated, and the linear regression has been plotted. It has been verified through Shapiro–Wilk tests that all the variables follow a non-normal distribution with a confidence level of 95%. Therefore, nonparametric statistical tests apply. For correlation analyses, the Spearman's correlation tests have been applied. Additionally, the standard deviation among the scores of the peer reviewers is calculated and represented for each sample using a color map.

From the results, all correlations (ρ) are significant ($p<0.001$) and they show a strong correlation between the two variables in all cases. This suggests that, in general, students perform well as evaluators. Notably, the correlation (ρ) for the second and third modules improves compared to the first workshop. This improvement can be attributed to the introduction of a rule mandating students to provide

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TABLE I
VIDEOS CONTAINING EXERCISES WITH WRONG METHODS AND/OR SOLUTIONS FOR THE THREE WORKSHOPS OF THE COURSE

Module of the course	**Basic Concepts/DC Systems**	**AC Circuit Analysis**	**Three phase AC systems**
Videos	Number/% total	Number/% total	Number/% total
With wrong solutions, methods, and or explanations	7 / 25%	3 / 10.7%	8 / 28.6%
Not detected by all the peers	4 / 14%	1/ 3.6%	6 / 21.4%
Not detected by at least one peer	0 / 0%	0 / 0%	2 / 7.1%

justifications in a designated box for different choices in the rubric form.

The calculation of the standard deviation between the scores assigned by the different peers also provides an interesting measure about the objectivity and trust from students acting as evaluators. In general, the deviations are acceptable and well-compensated when using the mean score to determine the final project grade. It can also be observed that, in many cases, exercises with high deviations between the grades assigned by the peers also differ from the grade assigned by the teacher. If instructors aim to reduce their workload when implementing this type of project, they could establish rules to select only specific videos for visualization. One such rule could be focusing on videos where the standard deviation between of the scores by the different peers is significant.

Table I provides a summary of the videos containing exercises that were executed using incorrect methods or had incorrect explanations or solutions across the three modules of the course. Table I also quantifies how many of these incorrect exercises were identified by the peers serving as evaluators. The results reveal that, out of the videos demonstrating students solving exercises, only 7, 3, and 8 contained errors or explained concepts poorly, constituting 25%, 10.7%, and 28.6% of the total, respectively. These errors were detected by all the peers in most cases.

Examining the particular results for each module of the course in Table I, it can be seen that in the first and second workshops, all errors and poorly explained concepts were successfully identified by at least one student serving as peer evaluator. However, during the final workshop of the course, there were two videos with minor errors that went undetected by at least one student, representing 7.1% of the total.

V. DISCUSSION

The implementation of the presented project has been very successful, considering the consistent results in the peer-review grading method, as well as the improvement in academic records and the feedback received from students, as shown in Section IV. The responsibility of assessing the assignments of their classmates has also empowered the students and notably boosted their motivation.

Overall, a remarkable increase in class participation has been observed, which is a relevant target in the teaching and learning process. An increase in class participation is often related to an increase in academic performance [36], [37]. Even though students' participation in educational settings is a multifactorial parameter, it is directly conditioned by their relationship with the instructor and the fear of peers' criticism. However, peers can also have a positive impact on the decision to participate in class, such as when the enthusiasm of a student can inspire others to participate more actively [38], [39]. The continuous peer-review methodology might also be positive in this regard, as students become used to being exposed to their peers' judgement during the course. Moreover, active methodologies, such as the one proposed in this study increase students' engagement and might foster the perception of a bi-directional path in the learning process where the professor is not the only source of information [40], [41], [42].

Furthermore, a rise in the number of tutoring requests during office hours has been quantified, which are now more distributed over the term. In the previous courses, all requests were concentrated in the few days leading up to the midterm and/or final exams; however, during this course, tutoring requests have been consistently received every week throughout the duration of the course. This can be explained by the distribution of the different tasks of the project over time, as shown in Fig. 2.

Based on the feedback obtained from students, one of the notable positive aspects remarked upon is the flexibility that the project offers to them. To complete each task, including video submissions and revisions, students were provided with a window of 7–10 natural days. This time allocation allows them to effectively manage their schedules, in contrast to the introduction of more continuous assessment tests that would require the establishment of specific dates and times for examination.

Moreover, an increase in academic performance has been quantified when comparing the experimental group with the control groups from three previous academic years. This aligns with [3], who highlight that learning by teaching could foster the generative processing that is necessary for significant and long-term learning. Such generative processing involves the active creation of a coherent representation of the studied material. This allows to organize and integrate the new information in a way that fits the learners' prior knowledge [4]. Furthermore, according to CTML, the use of video-based learning also reduces the essential cognitive load related to the inherent difficulty of abstract and complex topics, such as electricity. This is because the information is transmitted through a dual channel (auditory and visual), thereby reducing the cognitive demands [43], [44].

In addition to the improvement in academic outcomes, this project enabled students to acquire or improve competence related to creating educational materials, developing instructional videos, and presentation skills. These are key skills for digital competence, as defined by DigCompEdu framework [45].

From the results in Section IV-C, it can be concluded that peer evaluations from students are sufficiently reliable. The majority of errors and wrong explanations presented

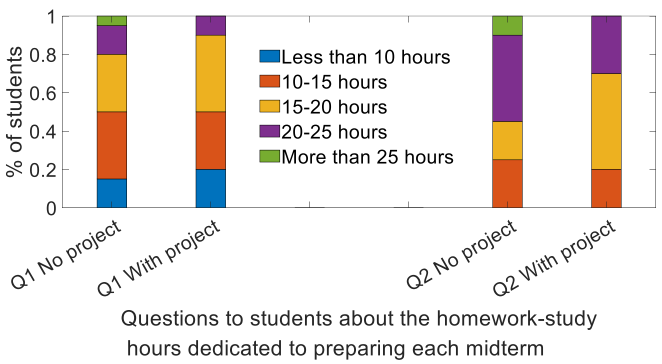

Fig. 8. Surveys to collect feedback from students of the academic year in which the project is implemented (with project) vs the previous academic year before the project (no project). Questions: Q1: How much time of study-work have you used on average to prepare each midterm exam? and Q2: How much time of study-work do you think is adequate on overall to prepare each mid-term exam?

in the video solutions were detected by students acting as evaluators. This aligns with current literature on peer-review methodologies, concluding that students acting as peer reviewers in properly designed educational settings often provide reliable reviews when comparing them with the teachers' evaluations [46], [47], [48]

However, as a means of further improving the results of the proposed peer-review methodology, the following two ideas will be implemented in future works: 1) increasing the number of students acting as peer reviewers and 2) assigning a higher weight to evaluations that deviate less from each other when calculating the final grade for the project submission.

Finally, concerning the time students dedicate to study and homework throughout the course, Fig. 8 displays the results of questions addressing this aspect, as obtained from surveys distributed to students in previous courses and during the course in which the project is implemented, respectively. According to the feedback received, students have dedicated fewer hours to preparing for the midterms, and they also perceive that a lower number of hours is needed for their preparation. The results suggest that after the implementation of this innovation project, students have improved their academic performance while dedicating less time to their studies. Such a conclusion is in consonance with the outcomes from [1], demonstrating that the exercise of explaining to fictitious others on video format might constitute a more effective learning activity before exams than restudy from the original learning material.

A. Impact of the Project on the Working Load of the Teachers and Challenges

The initial stages of the project involved a heavy workload, particularly during the design of the project, the elaboration of the evaluation sheets and the setup of the workshop tool. Additionally, during this first pilot course, each video solution was reviewed by the teacher. The main challenge now is to extend this methodology to groups with a larger number of students while avoiding an excessive workload for the instructors. With the demonstrated reliability of the evaluations provided by students, there is now greater confidence in the peer assessment process. The obtained results suggest the need to only revise the peer review form and to visualize videos when there is a significant deviation in scores assigned by the involved peers or when at least one reviewer has identified a mistake or inaccuracy. As mentioned earlier, increasing the number of peer reviewers per video can ensure a more thorough and equitable evaluation.

Once the project is fully underway, the workload becomes moderate, especially if not all student's videos need to be reviewed. Consequently, applying this project to courses with a larger number of students will require an effort that should be manageable. However, this approach has the drawback of not allowing the evaluation of the review quality by comparing it with the grade provided by the instructor. In this context, an alternative system could be implemented where penalties are applied to a student's own video grade if it is detected that they have conducted an unfair peer review of a classmate. From the authors' perspective, this limitation is not anticipated to significantly impact the overall project.

On the other hand, it is important to highlight that there was a noteworthy surge in student attendance during office hours. Despite this, the hours designated by the university for this responsibility remained adequate to address all students' inquiries throughout the course.

B. Applicability and Limitation of the Workshop Tool in Moodle

The workshop tool in Moodle has facilitated the implementation of the project presented in this article, as it is specifically designed for peer assessment and collaborative learning experiences. The use of customized rubrics in this project improves the consistency and objectivity of peer evaluations while maintaining anonymous assessment. Additionally, the feedback and interaction between peers contribute to continuous improvement in the subsequent tasks elaborated.

The tool automates aspects of the assessment process, such as the distribution of submissions and the collection of feedback, saving instructors time and streamlining the grading process. However, the initial configuration of the workshop tool in Moodle has been found challenging and not user-friendly. Teachers involved in the project have requested assistance from the digital department at their university for its suitable configuration. The main limitation has been that, with this tool, professors were not able to supervise the different stages of the process by using a student role, and they did not find extensive documentation or tutorials to resolve their doubts about the workshop tool.

Another functionality of the tool is that it can automatically evaluate how well the reviewers performed their task, allowing the teachers to choose between different evaluation methods for the reviewers (lax, strict, etc). However, explanations on the methodology implemented for the evaluation of the reviewer's performance in Moodle are not available in Moodle documentation, and the authors of this work were not able to understand or trust the provided results. In this project, the grades for the reviewers were assigned by the teachers manually.

VI. CONCLUSION

The implementation of an innovation teaching project based on the elaboration of peer review didactic videos in an electric circuits course is reported in this article. The proposed methodology integrates the benefits of four different pedagogical approaches, which are outlined in the introduction section, into a single project. The authors have found studies addressing these approaches separately, but no similar proposals have been found that combine all of them into a single comprehensive project, as presented in this research. The project achieved an improvement in the academic records of students and their homework study routine, while reducing the overall time dedicated to study and homework (RQ2). Additionally, students participating acquired new digital competence and presentation skills.

The implementation of the project required significant effort, but it is expected that the application of the project in the future will be relatively simple, allowing its implementation in courses with a larger number of students. According to the results of this experience, peer assessment proved to be reliable, and instructors can restrict the visualization of videos to specific cases, such as instances where grades assigned by different peers differ, or when reviewers identify mistakes in the solutions or explanations (RQ1). This change will significantly alleviate the workload of instructors, thereby facilitating the implementation of this project in courses with a larger student population. However, the proposed modification limits the evaluation of reviewer performance. In this regard, for future course implementations, the number of reviewers per video will be increased to enhance confidence in the evaluation. Additionally, the rubric form will be expanded to include more details.

Results obtained support the use of this kind of project. The authors anticipate continuing its implementation in the upcoming academic courses for this course. Given the positive results, future efforts will include applying the methodology to the engineering course "Magnetic Circuits and Transformers," which is coordinated by one of the authors at the same university. In this case, the video-based and peer review methodologies will foster both the conceptual and procedural learning, reinforcing the understanding of the course content and laboratory experiments. Additionally, a longitudinal study will be considered to assess the long-term effects of this teaching innovation project on students' academic and professional development.

APPENDIX A
RUBRIC FOR THE EVALUATION OF THE VIDEOS

Question 1 (Content of the Video (50%)):

1) The solution given to the problem is not explained or is incorrect. The problem is only solved in part.
2) The solution is correct, but the methods and equations applied are not well described and the info is not accurate or reliable.
3) The solution is correct; the solution methods are well applied but the equations are not properly described throughout.
4) The solution is correct, and the methods and the different equations used are properly described.
5) The video solves the problem clearly and concisely, including the detailed description of the solution methods and equations.

Question 2 (Quality of the Video (25%)):

1) The resources used to prepare the video are not adequate. The video is neither well organized nor adequate for educational purposes.
2) The resources used to prepare the video are adequate. The image and audio are not the most adequate for educational purposes and are not appealing.
3) The sound and visual quality are acceptable, but not especially appealing.
4) The video has good sound and visual quality for the standard of teaching purposes.
5) The video is well structured, visually appealing and the quality of the video is excellent.

Question 3 (Engagement of the Video (25%)):

1) The video is not valid as didactic material. It is not possible to follow the contents and the tone and pace are neither engaging nor enthusiastic.
2) The video is not recommended as didactic material. It is challenging to follow the contents and explanations. The tone and pace are not the most adequate.
3) The video could be used as didactic material because is clear, but the rhythm and tone are not engaging, and it is not easy to maintain attention.
4) The video is clear, concise, and easy to follow. It presents a good pace and tone and could be used as a good didactic material.
5) The video is an outstanding example for educational purposes. The tone of the video is engaging and enthusiastic and holds the attention throughout.

Question 4: Consider Incorporating Constructive Comments to Elucidate the Reasoning Behind Your Decisions.

APPENDIX B
GUIDELINES PROVIDED TO STUDENTS FOR PREPARING THE VIDEO AND CONDUCTING THE PEER REVIEW

Guidelines for Preparing the Video

Here are some recommendations to prepare your didactic videos.

1. Read the evaluation rubric and be aware of the items that are important for the evaluation.
2. Solve the assigned circuit in a paper or tablet, understanding all the methods and equations that you have applied to obtain the solution. It is fundamental that the solution proposed in the video is correct. Note that, the numerical solution is given in the exercise's sheets and in case of doubts you can also ask the teachers for help.
3. Prepare a script for your video, making sure that your video explains the basic laws, formulas, and principles that are relevant for the circuit solution.

4. Decide the format of your video (whiteboard and tablet…). It is not necessary that your image appears in the video, but at least your voice must be in it.
5. Record the video. It is important to make it didactic and easy to follow for other students.
6. Check the quality of the video before submitting it (image, sound, contents…). The maximum size of the file is 200 Mb and the requested format mp4.
7. Upload the video to Aula Global (doodle platform of UC3M) before the deadline.

Guidelines for Conducting Peer Reviews

The peer review process is blind for the student being evaluated but the whole process and complete information will be supervised by the teachers of the course. Be fair in evaluating your peers. Assigning unfair grades (both too high and too low) to your peers can negatively penalize your own grade. You will have to evaluate your peer videos according to the provided rubric form. For each question only one answer must be selected. Providing additional comments to justify your choices is mandatory.

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REFERENCES

[1] V. Hoogerheide, L. Deijkers, S. M. M. Loyens, A. Heijltjes, and T. van Gog, "Gaining from explaining: Learning improves from explaining to fictitious others on video, not from writing to them," *Contemp. Educ. Psychol.*, vol. 44–45, pp. 95–106, Jan. 2016, doi: 10.1016/j.cedpsych.2016.02.005.

[2] A. Lachner, L. Jacob, and V. Hoogerheide, "Learning by writing explanations: Is explaining to a fictitious student more effective than self-explaining?" *Learn. Instruct.*, vol. 74, Aug. 2021, Art. no. 101438, doi: 10.1016/j.learninstruc.2020.101438.

[3] L. Fiorella and R. E. Mayer, "Role of expectations and explanations in learning by teaching," *Contemp. Educ. Psychol.*, vol. 39, no. 2, pp. 75–85, 2014, doi: 10.1016/j.cedpsych.2014.01.001.

[4] R. E. Mayer, "Using multimedia for e-learning," *J. Comput. Assist. Learn.*, vol. 33, no. 5, pp. 403–423, Sep. 2017, doi: 10.1111/JCAL.12197.

[5] D. Mutlu-Bayraktar, V. Cosgun, and T. Altan, "Cognitive load in multimedia learning environments: A systematic review," *Comput. Educ.*, vol. 141, Nov. 2019, Art. no. 103618, doi: 10.1016/J.COMPEDU.2019.103618.

[6] G. Naveh and D. Bykhovsky, "Online peer assessment in undergraduate electrical engineering course," *IEEE Trans. Educ.*, vol. 64, no. 1, pp. 58–65, Feb. 2021, doi: 10.1109/TE.2020.3007853.

[7] M. Á. Conde, L. Sánchez-González, V. Matellán-Olivera, and F. J. Rodríguez-Lera, "Application of peer review techniques in engineering education*," *Int. J. Eng. Educ.*, vol. 33, no. 2, pp. 918–926, 2017.

[8] A. Mohan, D. Merle, C. Jackson, J. Lannin, and S. S. Nair, "Professional skills in the engineering curriculum," *IEEE Trans. Educ.*, vol. 53, no. 4, pp. 562–571, Nov. 2010, doi: 10.1109/TE.2009.2033041.

[9] M. Arias et al., "The master's thesis: An opportunity for fostering presentation skills," *IEEE Trans. Educ.*, vol. 57, no. 1, pp. 61–68, Feb. 2014, doi: 10.1109/TE.2013.2267094.

[10] T. J. Siller and A. A. Maciejewski, "Using student video presentations to develop communication skills." 2018. [Online]. Available: http://www.engr.colostate.edu/

[11] I. Galván-Sánchez, D. Verano-Tacoronte, S. M. González-Betancor, M. Fernández-Monroy, and A. Bolívar-Cruz, "Assessing oral presentation skills in electrical engineering: Developing a valid and reliable rubric," *Int. J. Elect. Eng. Educ.*, vol. 54, no. 1, pp. 17–34, Jan. 2017, doi: 10.1177/0020720916659501.

[12] M. Almasseri and M. I. AlHojailan, "How flipped learning based on the cognitive theory of multimedia learning affects students' academic achievements," *J. Comput. Assist. Learn.*, vol. 35, no. 6, pp. 769–781, Dec. 2019, doi: 10.1111/JCAL.12386.

[13] A. Shoufan, "Lecture-free classroom: Fully active learning on moodle," *IEEE Trans. Educ.*, vol. 63, no. 4, pp. 314–321, Nov. 2020, doi: 10.1109/TE.2020.2989921.

[14] M. Tani, M. Manuguerra, and S. Khan, "Can videos affect learning outcomes? Evidence from an actual learning environment," *Educ. Technol. Res. Develop.*, vol. 70, no. 5, pp. 1675–1693, Oct. 2022, doi: 10.1007/S11423-022-10147-3/TABLES/4.

[15] C. K. Lo and K. F. Hew, "The impact of flipped classrooms on student achievement in engineering education: A meta-analysis of 10 years of research," *J. Eng. Educ.*, vol. 108, no. 4, pp. 523–546, Oct. 2019, doi: 10.1002/JEE.20293.

[16] Ł. Tomczyk, M. L. Mascia, and F. D. Guillen-Gamez, "Video tutorials in teacher education: Benefits, difficulties, and key knowledge and skills," *Educ. Sci.*, vol. 13, vol. 13, no. 9, p. 951, Sep. 2023, doi: 10.3390/EDUCSCI13090951.

[17] R. Lijo, E. Quevedo, J. J. Castro, and R. Horta, "Impact of electrical engineering didactic videos during emergency remote learning," *IEEE Access*, vol. 11, pp. 19622–19634, 2023, doi: 10.1109/ACCESS.2023.3248299.

[18] V. Laparra et al., "Assessing the impact of using short videos for teaching at higher education: Empirical evidence from log-files in a learning management system," *Revista Iberoamericana de Tecnologias del Aprendizaje*, vol. 18, no. 3, pp. 233–238, Aug. 2023, doi: 10.1109/RITA.2023.3301411.

[19] D. Pattier, "Teachers and Youtube: The use of video as an educational resourcei," *Ricerche di Pedagogia e Didattica*, vol. 16, no. 1, pp. 59–77, 2021, doi: 10.6092/issn.1970-2221/11584.

[20] A. W. Tadbier and A. Shoufan, "Ranking educational channels on YouTube: Aspects and issues," *Educ. Inf. Technol.*, vol. 26, no. 3, pp. 3077–3096, May 2021, doi: 10.1007/s10639-020-10414-x.

[21] A. Shoufan and F. Mohamed, "YouTube and education: A scoping review," *IEEE Access*, vol. 10, pp. 125576–125599, 2022, doi: 10.1109/ACCESS.2022.3225419.

[22] F. Mohamed and A. Shoufan, "Choosing YouTube videos for self-directed learning," *IEEE Access*, vol. 10, pp. 51155–51166, 2022, doi: 10.1109/ACCESS.2022.3174368.

[23] B. Sridharan, J. Tai, and D. Boud, "Does the use of summative peer assessment in collaborative group work inhibit good judgement?" *High Educ.*, vol. 77, no. 5, pp. 853–870, May 2019, doi: 10.1007/s10734-018-0305-7.

[24] C. D. S. Melissa, M. Patchan, and R. J. Clark, "Accountability in peer assessment: Examining the effects of reviewing grades on peer ratings and peer feedback," *Stud. Higher Educ.*, vol. 43, no. 12, pp. 2263–2278, 2018, doi: 10.1080/03075079.2017.1320374.

[25] J. W. Nilsson and S. A. Riedel, *Electric Circuits*, 11th ed. London, U.K.: Pearson Educ., 2019.

[26] B. García and F. Arredondo, "Electrical power engineering fundamentals," Dept. Elect. Eng., Universidad Carlos III de Madrid, Getafe, Spain, Rep. OCW UC3M, 2021. [Online]. Available: https://ocw.uc3m.es/course/view.php?id=266

[27] A. A. Maciejewski et al., "A holistic approach to transforming undergraduate electrical engineering education," *IEEE Access*, vol. 5, pp. 8148–8161, 2017, doi: 10.1109/ACCESS.2017.2690221.

[28] J. M. Cabrera-Peña, E. Quevedo, H. Fabelo, S. Ortega, G. Marrero-Callicó, and A. Zapatera-Llinares, "Influence of the change of methodology in the practical laboratories of the power electronics subject," *Comput. Appl. Eng. Educ.*, vol. 29, no. 5, pp. 1358–1371, Sep. 2021, doi: 10.1002/CAE.22390.

[29] J. Wells, R. M. Barry, and A. Spence, "Using video tutorials as a carrot-and-stick approach to learning," *IEEE Trans. Educ.*, vol. 55, no. 4, pp. 453–458, Nov. 2012, doi: 10.1109/TE.2012.2187451.

[30] N. Colston, J. Thomas, M. T. Ley, T. Ivey, and J. Utley, "Collaborating for early-age career awareness: A comparison of three instructional formats," *J. Eng. Educ.*, vol. 106, no. 2, pp. 326–344, Apr. 2017, doi: 10.1002/JEE.20166.

[31] A. Tayebi, J. Gomez, and C. Delgado, "Analysis on the lack of motivation and dropout in engineering students in Spain," *IEEE Access*, vol. 9, pp. 66253–66265, 2021, doi: 10.1109/ACCESS.2021.3076751.

[32] P. Gregori, V. Martínez, and J. J. Moyano-Fernández, "Basic actions to reduce dropout rates in distance learning," *Eval. Program Plann.*, vol. 66, pp. 48–52, Feb. 2018, doi: 10.1016/J.EVALPROGPLAN.2017.10.004.

[33] A. Ayuso, N. Merayo, I. Ruiz, and P. Fernandez, "Challenges of STEM vocations in secondary education," *IEEE Trans. Educ.*, vol. 65, no. 4, pp. 713–724, Nov. 2022, doi: 10.1109/TE.2022.3172993.

[34] J. L. Poza-Lujan, C. T. Calafate, J. L. Posadas-Yague, and J. C. Cano, "Assessing the impact of continuous evaluation strategies: Tradeoff between student performance and instructor effort," *IEEE Trans. Educ.*, vol. 59, no. 1, pp. 17–23, Feb. 2016, doi: 10.1109/TE.2015.2418740.

[35] "Workshop activity." Moodle. Accessed: Nov. 29, 2023. [Online]. Available: https://docs.moodle.org/403/en/Workshop_activity

[36] J. Márquez, L. Lazcano, C. Bada, and J. L. Arroyo-Barrigüete, "Class participation and feedback as enablers of student academic performance," *Sage Open*, vol. 13, no. 2, Apr. 2023, Art. no. 21582440231177298, doi: 10.1177/21582440231177298/FORMAT/EPUB.

[37] E. Bekkering and T. Ward, "Class participation and student performance: A follow-up study," *Inf. Syst. Educ. J.*, vol. 19, no. 4, pp. 1–15, 2021. [Online]. Available: https://isedj.org/;https://iscap.info

[38] E. Severe, J. Stalnaker, A. Hubbard, C. H. Hafen, and E. G. Bailey, "To participate or not to participate? A qualitative investigation of students' complex motivations for verbal classroom participation," *PLoS One*, vol. 19, no. 2, Feb. 2024, Art. no. e0297771, doi: 10.1371/journal.pone.0297771.

[39] J. A. Fredricks, T. Hofkens, M. Te Wang, E. Mortenson, and P. Scott, "Supporting girls' and boys' engagement in math and science learning: A mixed methods study," *J. Res. Sci. Teach.*, vol. 55, no. 2, pp. 271–298, Feb. 2018, doi: 10.1002/TEA.21419.

[40] L. C. Hodges, "Student engagement in active learning classes," in *Active Learning in College Science: The Case for Evidence-Based Practice*. Cham, Switzerland: Springer, Jan. 2020, pp. 27–41, doi: 10.1007/978-3-030-33600-4_3/FIGURES/1.

[41] M. Odum, K. S. Meaney, and D. V. Knudson, "Active learning classroom design and student engagement: An exploratory study," *J. Learn. Spaces*, vol. 10, no. 1, Feb. 2021, Accessed: May 25, 2024. [Online]. Available: https://libjournal.uncg.edu/jls/article/view/2102

[42] F. M. Es Sánchez-González and D. Sánchez-González, "Fomentar la participación en clase de los estudiantes universitarios y evaluarla," *REDU. Revista de Docencia Universitaria*, vol. 17, no. 1, pp. 211–227, Jun. 2019, doi: 10.4995/REDU.2019.10702.

[43] R. E. Mayer and R. Moreno, "Nine ways to reduce cognitive load in multimedia learning," *Educ. Psychol.*, vol. 38, no. 1, pp. 43–52, 2003, doi: 10.1207/S15326985EP3801_6.

[44] R. C. Clark and R. E. Mayer, *E-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning*. Hoboken, NJ, USA: Wiley, 2016.

[45] C. Redecker and Y. Punie, *European framework for the digital competence of educators: DigCompEdu*, Publ. Office Eur. Union, Luxembourg City, Luxembourg, 2017, doi: 10.2760/159770.

[46] J. J. Serrano-Aguilera et al., "Using peer review for student performance enhancement: Experiences in a multidisciplinary higher education setting," *Educ. Sci.*, vol. 11, no. 2, pp. 1–21, Feb. 2021, doi: 10.3390/educsci11020071.

[47] N. Falchikov and J. Goldfinch, "Student peer assessment in higher education: A meta-analysis comparing peer and teacher marks," *Rev. Educ. Res.*, vol. 70, no. 3, pp. 287–322, 2000.

[48] H. Li, Y. Xiong, C. V. Hunter, X. Guo, and R. Tywoniw, "Does peer assessment promote student learning? A meta-analysis," *Assess. Eval. High Educ.*, vol. 45, no. 2, pp. 193–211, Feb. 2020, doi: 10.1080/02602938.2019.1620679.

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