IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received 28 May 2024, accepted 1 July 2024, date of publication 4 July 2024, date of current version 15 July 2024.

Digital Object Identifier 10.1109/ACCESS.2024.3423334

RESEARCH ARTICLE

Revolutionizing Electrical Engineering Education: A New Active Learning Method Based on Student-Generated Multimedia Content

RUBÉN BOLUDA-RUIZ, PEDRO SALCEDO-SERRANO, BEATRIZ CASTILLO-VÁZQUEZ, AND ANTONIO GARCÍA-ZAMBRANA

Wireless Optical Communications Laboratory, Telecommunication Research Institute (TELMA), Universidad de Málaga, 29010 Málaga, Spain

Corresponding author: Rubén Boluda-Ruiz (rbr@ic.uma.es)

This work was supported in part by the Innovation Teaching Project funded by the University of Málaga under Grant PIE22-051; in part by the Telecommunication Research Institute (TELMA); and in part by the Plan Andaluz de Investigación, Desarrollo e Innovación (PAIDI), in 2021, under Grant P21_00390.

ABSTRACT A novel active and collaborative learning approach that uses videos to enhance student participation and motivation in Electrical Engineering courses at the University of Málaga, is implemented. This work arises in response to the decline in student participation and motivation, which was exacerbated by virtual teaching during the COVID-19 emergency. This new approach leveraged students' inclination towards online video consumption, encouraging them to create educational videos. This not only fostered participation and motivation, but also improved the overall quality of learning. At the same time, by generating specific multimedia content related to the course, students were able to undoubtedly develop and strengthen essential transversal skills such as teamwork, oral communication, and critical and creative thinking. The experiment included a total of 50 students that were distributed between Circuits Analysis and Multimedia Information Transmission courses. Students were tasked with creating short videos using their creativity and ingenuity, and open-access software packages, focusing on course related content proposed by the professor. The evaluation of this learning method was conducted through two surveys: one before the activity and another upon its completion. The experiment results revealed a high level of satisfaction with this methodology and high success in achieving the main objective, concluding the grade of maturity and responsibility of involved students present a remarkably impact. These results also allow us to conclude that the strategic integration of videos as an educational tool in Electrical Engineering Degrees can increase student participation and motivation by providing a more attractive, interactive, and contextually relevant learning experience. Therefore, it is hoped that this study will serve as an example and as a practical and accessible guide for all those interested in implementing similar strategies in their own educational environments.

INDEX TERMS Participation, motivation, engagement, video, education, electrical engineering, STEM.

I. INTRODUCTION

In the current higher education academic context, the integration of innovative pedagogical approaches is considered essential to address important academic challenges such as the decrease in student motivation and participation. The COVID-19 pandemic emphasized the need for teaching methods that are adaptable and effective in the new scenario that was presented. The pandemic also required a rapid transition to virtual learning, undoubtedly altering the traditional teaching methods and exacerbating the pre-existing challenges in student motivation and engagement. In view of this unprecedented situation, Information and Communications Technologies (ICTs) played a key role in ensuring

The associate editor coordinating the review of this manuscript and approving it for publication was James Harland.

that education continued at all levels [1]. A few years after the pandemic, we find ourselves in a complex academic context in which the level of motivation and participation of students in higher education has decreased drastically [2], particularly in degrees in the field of STEM disciplines (Science, Technology, Engineering and Mathematics) due to this period of virtual learning [3], [4]. In this way, providing solutions to address this situation has become crucial from an academic point of view. The relationship between motivation and participation in the university environment is extremely complex. Furthermore, both are interconnected in several ways and play a decisive role in the student's academic success and the overall learning experience. This paper presents a pilot study on the use of student-generated videos as an active and collaborative learning method. The aim is to revitalize the interest, motivation, and participation of the undergraduate students in some courses of the Degree of Electrical Engineering at the University of Málaga. It is important to highlight that many students and teachers have demonstrated resilience and adaptability to the challenges that have arisen in the academic world in recent years. Hence, many students maintain levels of motivation and participation in class similar to those they had before the pandemic.

In the present-day society, students operate in an environment saturated with digital technology. These students, considered as *digital natives*, have cultivated an inherent familiarity with the consumption of multimedia content through different online platforms such as social networks, video on demand services, educational channels on YouTube [5], [6], among others online platforms. This technological immersion has shaped not only their current information consumption patterns, but also their expectations and preferences in academia. The ubiquitous presence of digital devices has generated an expectation among university students of an educational approach that reflects and leverages their modern communication and media consumption habits. The effective integration of multimedia resources, adaptability for use on mobile devices, and the implementation of interactive teaching methods have become decisive in attracting and maintaining their commitment to the learning process. Because the ICTs sector is constantly evolving, it is evident to adjust pedagogical strategies in university education to align with the expectations and abilities of these *digital natives*, taking advantage of the abundance of resources available to enrich their academic experience.

A. LITERATURE REVIEW

Next, a review of the current state of the art regarding the use of multimedia resources as a learning method in the university environment is provided, particularizing for STEM degrees. In this context, the use of multimedia resources in the university environment has experienced a significant growth in recent years, especially driven by the transition to virtual teaching during COVID-19 [7], [8], [9], [10]. This evolution has transformed the way of teachers design and deliver learning materials, and the way of students access to information [11].

The use of multimedia resources of different types can be defined as the presentation of verbal and visual academic content simultaneously [12]. In 1997, Mayer defined multimedia learning as a learning process that contains both images (video or animation) and words (verbal or written text) [13]. In the last two decades, numerous research and studies have been conducted [14], [15] (and references therein). In [14], it is concluded that audiovisual content offers benefits in the learning process when designing effectively. In [15], it is even shown that students learn better by viewing multimedia content as it contains words and graphics instead of just words. In fact, the visual and auditory nature of the content facilitates the understanding of complex concepts, allowing students to learn more effectively and retain information over the long term [16]. The ability to visualize abstract concepts, observe procedures, and access to multimedia material enriches the learning experience, providing a more practical and applied perspective. The use of multimedia resources as a learning method has also been combined with active learning methods, seeking to increase the levels of motivation and participation of students [17], [18]. The literature also concludes that to improve the learning experience in courses with high abstract content, as in Engineering Degrees in general and, particularly, in those related to Electrical Engineering, it is necessary to properly use the multimedia resources to improve academic performance [19], [20]. On the other hand, the adoption of online platforms as the main teaching method has accelerated, leading to a significant increase in the creation and consumption of educational content on YouTube [21], [22]. The YouTube platform is an excellent opportunity for both formal [23], [24] and informal [25] education. During the virtual teaching period, this platform gained enormous popularity by supporting teachers and students in distance learning [26], becoming an essential resource for university students, and offering a wide range of content, from tutorials and classes to practical demonstrations. Despite the benefits, it is important to address some challenges associated with the use of multimedia content in university education. The quality of the content, the veracity of the information and the need to accompany multimedia resources with evaluations and interactive activities are necessary considerations to guarantee the effectiveness of learning. Likewise, it is essential to wonder what degree of understanding is perceived by students after viewing audiovisual content related to the course and provided by the teacher, as well as how to evaluate such a degree of understanding.

Currently, the aim is to make the students actively participate in the generation of didactic content and in the construction of their knowledge, with the help of online learning tools. The term student-generated content was proposed to describe materials that students create, for example, for their own benefit, or as assignments within the learning process, as well as to contribute to the learning of other classmates. Multimedia content, which can range from blogs and images to Wikis, summaries of teaching material, videos, among other formats, can be generated spontaneously or as part of course activities that require the creation of learning support resources [27], [28], [29], [30]. Student-generated questions are also implemented in STEM education [31], [32], [33]. In [31], the learning experience is improved by using sharing multiple-choice questions among students. In [32], GPT-3 is used to asses the quality of student-generated short questions. In [33], student-induced questions are implemented in Mathematics to foster the learning experience. In particular, some studies based on student-generated content in video format have been published as a learning method in different areas [34], [35], [36], [37], [38], [39], [40]. This literature review is listed in Table 1, where the most relevant articles are categorized by their main purpose. In [34], the use of student-generated content is analyzed as a strategy to increase participation, commitment, emotion and learning of the students themselves. In this study, students are tasked to create YouTube videos that reflect what they have learned during lectures in the Degree of Aerospace Engineering at Southern Polytechnic University in Marietta, Georgia. In [35], the dynamic generation of digital content by students and its integration into shared knowledge bases of the involved courses is addressed, among other aspects of interest, at the University of the Basque Country, Spain. In [36], the authors focused on the growing interest and popularity of student-generated videos in Chemistry education. The interest in the use of these videos in the field of Chemistry is based on the visual nature of the discipline and the crucial role of laboratory work. In [37], science students collaborate with Digital Media students to create educational videos that explain scientific concepts, primarily focusing on outreach activities at Georgia Gwinnett College. In [38], the authors examine replacing written reports with student-generated videos in a Management Information Systems course that emphasizes hands-on skills at The Hong Kong Polytechnic University. In [39], student-generated activities for learning STEM courses are explored in Malaysian universities. Lastly, in [40], the development of robust student-generated video resources for Chemistry lab sessions is investigated. However, to the best of our knowledge, the existing literature, regarding the generation of videos by students as a learning method in the field of Electrical Engineering, shows a notable lack of studies. Despite the growing relevance of this practice in other disciplines, the lack of detailed studies and global comparisons is evident, highlighting the urgent need for studies that explore the effectiveness and challenges associated with this method in this discipline. As in Chemistry, as well as in other disciplines, the interest in the use of these videos in Electrical Engineering is based on its practical and multidisciplinary nature, and the decisive role of the laboratory work.

TABLE 1. Categories of student-generated content in STEM education.

Purpose	References
Student-generated YouTube videos to enhance participation, commitment and emotion in Aerospace Engineering.	[34]
Dynamic generation of digital content by students integrated into shared knowledge bases of different courses.	[35]
Exploration of student-generated videos in Chemistry education, emphasizing the visual nature and laboratory work in the discipline.	[36], [40]
Student-generated content for outreach activities in Chemistry education.	[37]
Replacement of written reports with student-generated videos.	[38]
Student-generated activities by using videos in STEM education.	[39]
Student-generated questions in Mathematics and other disciplines.	[31]–[33]

In relation to student-generated content, some authors in the literature point out that involving the students in content creation can lead to extensive repositories of useful learning resources, reducing the burden on teachers [41], [42]. The main objective of this study is to actively involve students in the creation of multimedia content as an active and collaborative learning method, and not precisely to reduce the burden on teachers. The approach followed by this study is more aligned with another trend of thought that firmly believes that students possess valuable insights into teaching and learning, which can enhance educators' practices [43]. Encouraging students to engage in content creation not only deepens their understanding of the course syllabus, but also fosters active participation in their learning process. By creating content, students gain a deeper awareness of their own learning journey while also contributing to the learning of their peers [44], [45], [46]. At the same time, the process of creating a video can evoke active, collaborative and creative characteristics that have been shown to lead to a higher level of motivation and positive emotions [47]. The multimedia content produced by the students themselves has the power to benefit students in both more theoretical and practical concepts by facilitating their learning, and developing and/or strengthening transversal skills, such as oral communication [48], [49].

Despite the potential benefits of this practice, many authors are concerned about the educational value of some student-generated content, as it may present conceptual errors [50]. Therefore, it becomes more than evident that before such a content can be widely used, it is necessary to perform an evaluation process to distinguish between low- and high-quality resources [51]. Some authors have emphasized the small number of articles that exhaustively address how this evaluation process can be performed [52]. Firstly, in terms of the choice of specific criteria and their alignment with the understanding of the students about a quality resource and, secondly, about how they could be formalized through rubrics and the impact of these on the students' evaluation activity.

B. MAIN CONTRIBUTIONS

This study, for the first time, reports the implementation of a methodology based on the creation of multimedia content by the students, with the purpose of addressing the low motivation and participation observed in Electrical Engineering courses. Unlike the existing literature, this initiative not only seeks to increase motivation and participation, but also strengthen transversal skills such as oral communication, teamwork and critical thinking. Furthermore, it is expected that this innovative learning method will improve the understanding and assimilation of the theoretical-practical contents of the courses. The general objective of this study is then to revitalize the educational process through the design and implementation of an activity that applies an innovative methodology using video as a supporting tool, allowing students to generate multimedia content of a didactic nature in mandatory Electrical Engineering courses. For this purpose, the first step will be to design the activity based on a specific methodology, as will be seen in Section II, for each of the courses considered in this study: *Circuits Analysis* (CA) and *Multimedia Information Transmission* (MIT). Next, the main contributions of this study are listed:

- We address the decrease in student motivation and participation by implementing a new active and collaborative learning method. The level of motivation and participation is evaluated before and after the implementation of the activity through questionnaires, as will be seen in Section III. The implemented activities are original, to the best of our knowledge, and have not been previously conducted in the context of student-generated videos. In addition, the level of interaction and enthusiasm is also observed during lectures and after the completion of the activity.
- We improve the quality of learning through the creation of multimedia content by the students. The degree of understanding and assimilation of the theoretical-practical contents of each course is measured by conducting a final test at the end of the semester. Besides, the final grades of students who participated in the activity is compared with those who did not.
- Through the generation of multimedia content, the students will be able to develop and strengthen transversal skills of oral communication, teamwork and critical thinking, among others. The strengthening of these skills is evaluated by observing the quality of the content generated, the ability to work as a team, and the ability to constructively analyze and criticize the work of their classmates.

This comprehensive evaluation allow a deep understanding of the impact of this active and collaborative learning method based on the didactic video generation. In addition, the degree of student satisfaction and the supervision and teaching performance during the activity is also measured, among other aspects of interest. Finally, this pilot study is intended to serve as an example and as a practical and accessible guide for all those interested in implementing similar strategies in their own educational environments. The results allow us to conclude that the strategic integration of videos as an educational tool in Electrical Engineering Degrees can increase student participation and motivation by providing a more attractive, interactive, and contextually relevant learning experience. The experiment results revealed a high level of satisfaction with this methodology and high success in achieving the main objective, concluding the grade of maturity and responsibility of involved students present a remarkably impact. The results demonstrated that the act of creating audiovisual content enhances students' understanding and retention of information.

C. ORGANIZATION OF THE PAPER

The balance of the paper is organized as it follows. Section II describes the novel methodology based on student-generated multimedia content, as well as the specific methodology for the considered courses: CA and MIT. In Section III, the main findings of the study are presented and analyzed from a statistical point of view, shedding light on the implications of the implemented methodology. Next, Section IV offers the conclusions drawn from the study, summarizing the key insights derived from this research. Finally, Section V discusses potential future implementations and improvements to the implementation of the methodology, offering avenues for further exploration and development.

II. METHODOLOGY

In this section, the methodology applied to implement the proposed activity is described. It is important to recall that the aim of this activity is to increase the levels of motivation and participation among undergraduate students in degrees related to Electrical Engineering as a result of the decline caused by the COVID-19, as well as to strengthen transversal skills such as oral communication. Hence, an active and collaborative learning method based on student-generated videos is for the first time proposed in this field. The objective of applying this novel approach is to take advantage of the potential of multimedia content as a method of learning. This methodology is applied in two courses: CA and MIT, both taught by the Department of Communications Engineering at the University of Málaga.

Currently, there are various technological options available to simplify video recording for students. Modern Apple and Android devices offer easy-to-use interfaces for effortless video recording. Additionally, free screen recording tools like OBS (Open Broadcaster Software) and screen recording features in Microsoft PowerPoint are accessible. Hence, for creating multimedia content, we suggest utilizing free software such as OBS and Microsoft PowerPoint, although students may opt for other choices. Free video editing programs can be used to enhance the content with text, images, or other features.

A. PHASES OF THE STUDY

The implementation of the experiment was divided into five phases: Preliminary phase, Video creation phase, Video evaluation phase, Final phase, and the Data analysis phase. Firstly, the Preliminary phase properly assess the impact of creating videos as an activity on the learning process of both courses by conducting a pre-questionnaire (PRE-Q). This aims to understand students' perception regarding the importance of enhancing not only the learning experience, but also motivation, participation, and oral communication skills for potential future professional career, along with other aspects related to multimedia content creation. This phase is planned at the beginning of the semester, serving as a baseline for measuring changes and progress throughout the learning process.

In the Video creation phase, each student or group of students, depending on the course, is tasked with creating multimedia content to solve exercises and/or explain concepts or practical scenarios based on the academic content of each course. The specific methodology of each course will be presented in the next subsections. This phase remains active throughout the time allocated for students to develop the activity.

In the Video evaluation phase, the student-generated content is evaluated. To do that, peer review is used to ensure clear and precise language, good organization, and technical quality of the content. Specific evaluation criteria include whether the activity aided in achieving learning outcomes alongside lectures. This evaluation is planned at the end of the semester once students have completed the activity.

In the Final phase, the impact of the activity is analyzed by conducting a final questionnaire (POST-Q). This aims to evaluate changes in motivation, participation, learning through video creation, workload, effort, and potential use of the generated videos for study purposes, among other key aspects. This is the last task for students and is planned at the end of the semester.

Finally, in the Data analysis phase, data from PRE-Q and POST-Q questionnaires are analyzed comprehensively to assess the effect of student-generated video on motivation, participation, oral communication skills, understanding of course concepts, and overall academic performance. The aim is to quantify the impact on students' final grades in both courses and potentially extend the proposed methodology to other STEM disciplines.

Below, the specific methodology is presented for each of the courses in which the proposed activity has been implemented.

B. SPECIFIC METHODOLOGY FOR CIRCUITS ANALYSIS

CA is a 60-hour course taught during the first semester of the first year of the Electrical Engineering Degree. It is a Basic Training course corresponding to the Circuits and Systems field. In this course, which is structured into four topics, students learn the foundations of the Circuit Theory and systematic techniques for analyzing electric circuits, focusing also on analyzing electric circuits in a sinusoidal steady state.

For each topic of the course, each student must individually create a video with the solution to an exercise included in the exercise list for the respective topic. Performing the activity individually allows each student to demonstrate their personal understanding and skills in applying the Circuit Theory. Additionally, a video duration of no more than 7 minutes is recommended, during which the fundamental steps leading to problem resolution are described through audio, with the optional student presence. A 7-minute duration allows students to address each step more slowly and in detail, facilitating a complete understanding of the circuit resolution process. Circuit Theory involves detailed steps in problem-solving. Problem-solving in CA requires a deep understanding and individual application of the theoretical concepts.

In general terms, the problem involves analyzing a specific electrical circuit, i.e., determining the voltage and/or current in one or all elements that consists of the electrical circuit in question. Thus, students can record their own videos solving the exercise while explaining the entire resolution process and justifying all decisions made when performing the exercise. These videos are recorded and can be used later as study materials for future students, once they have been evaluated and with their prior authorization.

In Appendix, four typical exercises associated with each of the didactic topics for the activity are provided as examples. Finally, regarding the evaluation of each video, this will be carried out using a rubric with 4 levels (1-Deficient, 2-Regular, 3-Satisfactory, and 4-Excellent) that assess each of the following aspects:

- Q1: Is the exercise statement presented correctly, indicating what is requested, with all necessary data, and a well-defined representation of the electric circuit?
- Q2: Is there an initial preamble contextualizing why a particular path is chosen when solving the exercise?
- Q3: Are each of the steps taken to solve the exercise clearly indicated?
- Q4: Once the exercise is solved, is there a brief global review of everything done?
- Q5: Has the student used a clear and precise language, presenting relevant ideas in an organized manner and properly referring to each circuit element and variable?

C. SPECIFIC METHODOLOGY FOR MULTIMEDIA INFORMATION TRANSMISSION

MIT is a 60-hour course taught during the first semester of the third year of the Electrical Engineering Degree. It is a mandatory course corresponding to the Specific Technologies field. In this course, which is structured into six topics, the foundations of Information Theory formulated by Claude Shannon are established, including basic knowledge of compression methods for multimedia data such as audio, image, and video, and issues related to multimedia data transmission over the Internet.

Because MIT is a third-year course, students possess a higher level of maturity and accumulated knowledge, resulting in a more challenging activity compared to the one proposed in CA, which is a first-year course. The activity involves creating a group video with four members on multimedia source coding and compression, which is the core of the course. Each group will produce its own video explaining a scientific article in English, chosen by the teacher, focusing on the key aspects related to information encoding and compression and applying concepts learned during lectures. Working in small groups facilitates task allocation, allowing for a dynamic and varied presentation. Additionally, group work encourages idea exchange and collective problem-solving. Unlike the recommended duration of no more than 7 minutes for the activity in CA, a video duration of no more than 4 minutes is advised here. Through audio, images, text, and the optional group member presence, the article will be explained. Understanding a scientific article in English may involve technical and detailed concepts beyond the course's curriculum. Thus, limiting the duration to 4 minutes enables students to focus on the most important aspects and enhances comprehension. Furthermore, a 4-minute duration ensures students maintain attention and concentrate on presenting the most relevant and essential aspects of the article.

To aid in understanding the article, some questions associated with each scientific article are provided to guide the video content. Similar to CA, the recorded video can be used later as study material for future students, once they have been evaluated and with their prior authorization. Additionally, this activity aims to fulfill the explicit learning outcomes outlined in the Electrical Engineering B.Sc. Specifically, it aims to achieve those learning outcomes related to understanding and handling technical and scientific documentation primarily written in English. To facilitate this, the activity based on student video creation is proposed as an innovative and enjoyable way to address the issue while enhancing oral communication skills.

Regarding the selection of scientific articles for the proposed activity, it was not a simple task due to the broad spectrum of multimedia information transmission and the numerous technological advancements in this field. The challenge was to find articles that, despite their technical complexity, were somehow aligned with the level of knowledge acquired during lectures, enabling students to effectively tackle the task of explaining new concepts in Spanish through video production. Each article was carefully chosen to provide students with a comprehensive experience covering the historical evolution of multimedia signal processing to cutting-edge technologies, such as the application of artificial intelligence and next-generation video compression standards like Versatile Video Coding (VVC) or H.266 [53], [54], [55], [56], [57], [58]. The variety of selected topics aims not only to consolidate theoretical knowledge acquired in lectures but also to challenge students to explore practical applications and current and future trends in this dynamic and ever-evolving field. It should be noted that other scientific articles could have been selected to implement the activity. Note that a total of six articles were selected as a total of six groups participated in the activity. The databases of IEEE Xplore, Scopus, Web of Science, ScienceDirect, among others, are full of scientific articles that meet the requirements to be selected in this activity.

In Appendix A, two of the selected scientific articles for the activity, along with a set of guiding questions for students to produce the video, are provided as examples. Finally, regarding the evaluation of each video, this will be carried out using a rubric with 4 levels (1-Deficient, 2-Regular, 3-Satisfactory, and 4-Excellent) that assess each of the following aspects, considering criteria related to content clarity, creativity and originality, as well as interaction and participation of different group members:

- Q1: Is the theme and scope of the scientific article clearly introduced?
- Q2: Does the group use visual or graphic resources creatively to support the explanation of the scientific article?
- Q3: Are practical examples or case studies incorporated in an original way to illustrate the presented concepts?
- Q4: Is there an equitable distribution of participation among group members?
- Q5: Does the group demonstrate a solid understanding and effectively discuss the more technical aspects of the scientific article?

As can be noted, the proposed activity consists of creating multimedia content related to each of the considered courses. It is worth noting that although the general objective of the proposed activity is the same in both courses, and the activity itself is based on the generation of multimedia content, the planned activity is different for each course due to the following reasons. Firstly, CA is a first-year course and falls under the category of Basic Training, covering, among other topics, the fundamentals of Circuit Theory. Hence, the activity will focus on creating videos on how to correctly and efficiently solve typical exercises of the course, i.e., learning to analyze elementary electric circuits. In contrast, MIT is a third-year course and falls under the category of Specific Technologies, presenting a more descriptive than practical nature compared to CA, as it establishes the fundamentals of coding and compression of multimedia sources. Secondly, due to the level of academic maturity and accumulated knowledge of the students in MIT compared to those in CA. The planned activity for MIT is different because the aim is for students to acquire competencies in understanding scientific and technical texts in English.

III. RESULTS AND DISCUSSION

In this section, using a statistical approach, the obtained results are analyzed and discussed. The analysis of these results is carried out by conducting two questionnaires: one before the execution of the activity (PRE-Q) and another one upon its completion (POST-Q). The sample of this study included a total of 50 students: 28 belonging to CA (60% of participation in relation to the total number of enrolled students), and 22 to MIT (88% of participation in relation to the total number of enrolled students), as depicted in Fig. 1. The data was collected during a period of 15 weeks, i.e., one semester corresponding to the 2023/2024 academic

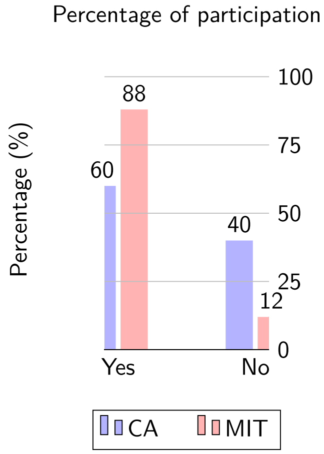


FIGURE 1. Bar diagram associated with student participation in the proposed activity.

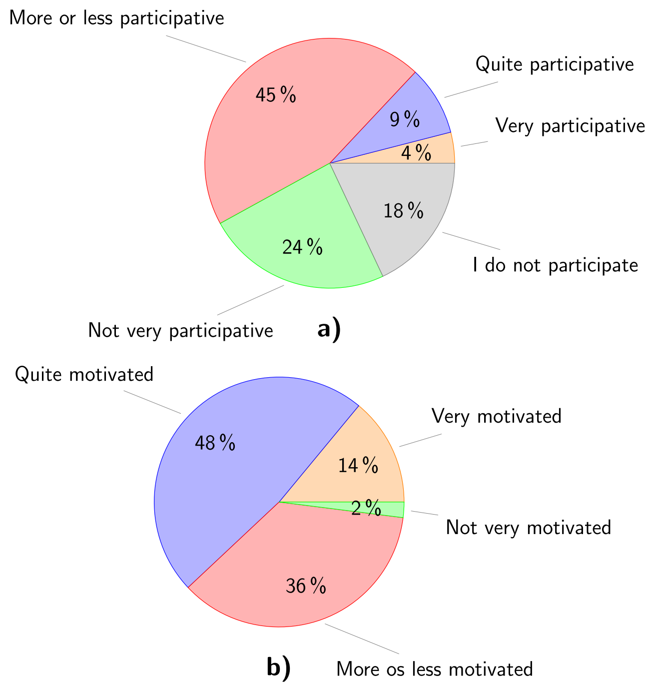


FIGURE 2. Total statistical results for questions related to a) motivation and b) participation in both courses.

year. In both surveys, the students individually answered a total of 18 questions, addressing key aspects such as commitment, organization, learning and effort, among others. It should be noted that this study does not address gender differences, although it is segmented by age. CA belongs to the first academic year with students around 18 years old, while MIT belongs to the third academic year with students around 20 years old. Regarding gender, an under-representation of women was observed with 16 women out of 50 students (32%). In relation to confidentiality, all students who participated in the activity provided their consent for the scientific use of the data collected. Responses to the questionnaires were completely anonymous.

A. STUDENTS' PERCEPTIONS: PRE-Q ANALYSIS

In Table 2, the results corresponding to the PRE-Q questionnaire are shown. Regarding class participation, it can be seen that 45% of students consider themselves "More or less participative", while 24% identify as "Not very participative". These percentages indicate a potential gap to foster more active participation during classes. A comparison between both courses reveals that 50% of CA students define themselves as "Not very participative" or "I do not participate", compared to 19% of MIT students. While both courses suggest receptive students to participation-stimulating strategies, the disparity in participation levels could indicate the need for differentiated approaches to promote engagement, adapting to the particularities of each course. Concerning motivation and learning experience, it is observed that 62% of students feel "Very motivated" or "Quite motivated" regarding the course's themes. Furthermore, 39% have engaged in activities to enhance their learning experience before entering university, highlighting the positive influence of previous experiences in academic formation, contrasting with 44% who do not recall engaging in such activities. In Fig. 2, a graphical summary highlighting significant aspects related to motivation and participation is provided, aiming to improve comprehension of the statistical data presented in Table 2. Additionally, it is positively noted that 41% of students believe they possess the ability to communicate orally through self-recorded videos. However, 44% are uncertain about their ability to communicate orally through self-generated videos, indicating a space for improvement and work to strengthen such cross-cutting skills. Furthermore, 40% of students do not consider themselves skilled in generating multimedia content, whereas 35% acknowledge being accustomed to creating videos.

More importantly, 79% of students believe that generating multimedia content could enhance their learning experience, potentially serving as study material. This perception underscores the relevance students attribute to audiovisual skills as effective learning tools. The table data also demonstrate students' awareness of the importance of enhancing oral communication skills during their university years, scoring 8.3/10 in the question related to the necessity of strengthening oral communication upon leaving university. The table also reveals a score of 3.7/5 regarding the perception that undergraduate studies should contribute to improving communication skills, reflecting a moderately high expectation of university education in this aspect. This result supports the idea that students recognize the importance of developing communication skills during their university education, beyond the acquisition of technical knowledge.

B. PEER ASSESSMENT

As part of the learning process, peer assessment is here applied to evaluate the videos generated by the students during the implementation of the activity by using the

TABLE 2. Statistical results corresponding to the previous questionnaire (PRE-Q).

Question	Restriction	CA	MIT	Overall results
Do you consider yourself a participative student in class? That is, do you ask questions, try to solve doubts in class, share your concerns, and curiosities?	Very participative	3%	5%	4%
	Quite participative	5%	18%	9%
	More or less participative	42%	58%	45%
	Not very participative	28%	14%	24%
	I do not participate	22%	5%	18%
How would you assess your level of motivation in relation to the course, prior to its delivery?	Very motivated	12%	18%	14%
	Quite motivated	45%	55%	48%
	More or less motivated	40%	27%	36%
	Not very motivated	3%	0%	2%
	Without motivation	0%	0%	0%
Have you done any activity aimed at improving the learning experience in a course and, at the same time, learning how to communicate orally?	Don't know/No answer	15%	23%	17%
	No, I don't remember any	45%	41%	44%
	Yes, during my pre-university stage	40%	36%	39%
Do you believe you have the necessary skill to generate audiovisual content in the style of Instagram Reels, TikTok videos, among others?	Don't know/No answer	21%	36%	25%
	No, I don't consider myself good at creating videos	48%	18%	40%
	Yes, I am accustomed to creating videos	31%	45%	35%
Do you believe you can communicate orally through a video recorded by you?	Don't know / No answer	4%	0%	4%
	No, I am not capable	16%	0%	11%
	I am not sure	47%	36%	44%
	Yes, of course	33%	64%	41%
Do you think that the generation of audiovisual content could help you improve the learning experience, potentially even being used as study material?	Don't know/No answer	12%	9%	11%
	No, I consider that it would not be a good learning method	9%	14%	10%
	Yes, I consider that it can be a good learning method	79%	77%	79%
When you leave the University, do you think you will need to be able to communicate orally?	Please indicate the level on a scale of 1 to 10, with 1 being "Basic" and 10 being "Expert."	8.3/10	8.3/10	8.3/10
Do you consider that the studies you are pursuing should help you improve your ability to communicate orally or in writing?	Please indicate the level on a scale of 1 to 5, with 1 being "No, the Degree should only train me in technical matters" and 5 being "Yes, the Degree is responsible for this training."	3.8/5	3.5/5	3.7/5

rubrics provided at the end of the subsections II-B and II-C. In this experiment, peer assessment has been used for strictly educational purposes, using a non-anonymous form. Furthermore, the evaluations carried out did not affect the students' final grade. This decision was made with the intention of encouraging students to evaluate the quality responsibly, minimizing their concerns regarding grades or the influence of positive or negative relationships with other classmates. As teachers, we do evaluate all student work. It should be noted that the fear of increasing the workload of teachers involved in supervising students' work could be an obstacle, mainly in CA, since it has a larger number of enrolled students compared with MIT. Therefore, it was proposed to the students to carry out the activity voluntarily. Unlike [34], in whose study some students found the experience frustrating due to the difficulty in generating multimedia content, we have not encountered this problem.

According to the results obtained in CA, it is observed that the averages of the evaluations for each of the videos associated with each of the didactic topics indicate that the students received positive scores on average. The total average is 7.5/10, allowing us to conclude a favorable evaluation overall, taking into account that they are first-year students. Some variability was also observed in the evaluations, reflected in a standard deviation value of 3.5. Higher values would indicate a greater dispersion in the evaluations received. It is worth highlighting the consistency in the evaluations, the average ratings tend to be quite consistent between the different videos, with gradual increases. This could indicate that the perceived quality of the videos gradually improves as the students have progressed through the semester, as well as their oral communication skills have improved. On the other hand, it could also indicate a certain consistency on the part of the students during the evaluation process. Hence, it is concluded that, given that the mean scores and standard deviations do not show extremely high or low values, the students positively evaluated the videos among themselves in this course.

On the other hand, considerable variability is observed in the scores between the groups of the activity implemented in MIT (a total of six groups), unlike the individual scores obtained in CA, with scores ranging from 6.5/10 to 9.0/10. This indicates that the perceived quality of the evaluated works differs significantly between the different groups. One of the groups stood out with the highest score of 9.0/10, indicating that their work was evaluated as exceptionally

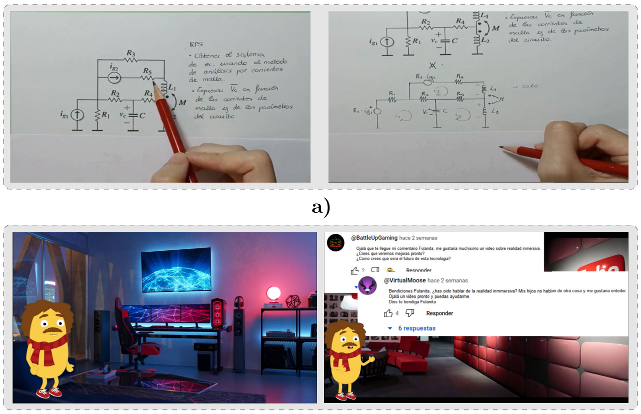


FIGURE 3. Two non-consecutive frames corresponding to two of the videos generated by the students in the context of the activity proposed both in a) CA and b) MIT courses.

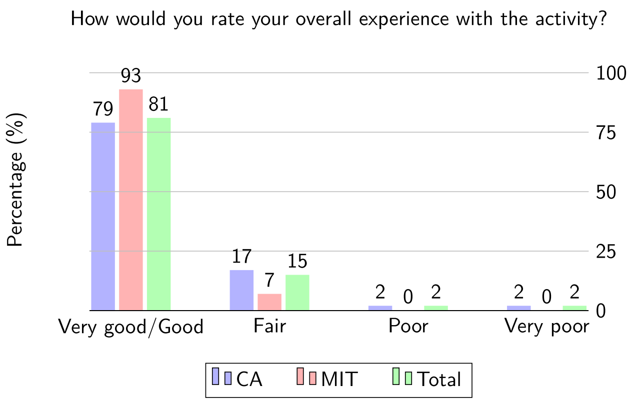


FIGURE 4. Bar diagram associated with the statistical results related to the general experience with the proposed activity.

good compared to the other groups. The general average of all scores was 8.1/10 with a standard deviation value of 1.15, reporting a generally positive performance in the peer evaluation in MIT. The standard deviation of 1.15 indicates some consistency in the scores, although there was variability between groups. In Fig. 3, two non-consecutive frames corresponding to two of the videos generated by the students in the context of the proposed activity are illustrated.

C. STUDENTS' PERCEPTIONS: POST-Q ANALYSIS

In Table 3, the results corresponding to the POST-Q questionnaire are shown. In relation to the overall experience with the activity, 81% of students rated the experience as "Very good" or "Good", as can be seen in Fig. 4. This level of acceptance suggests that the methodology used, along with the practical implementation of communication and audiovisual skills, was effective and stimulating for the students. Although both courses reflected a positive reception, MIT exhibited a more pronounced inclination towards "Very good" ratings, 50% compared to 33%, suggesting higher satisfaction compared to CA, despite having fewer participants. The majority of students, 4.1/5 on average, perceived that the activity significantly contributed to understanding the academic objectives of the involved courses. This high rating reinforces the idea that the activity not only provided an enriching experience, but also fulfilled its fundamental educational purpose. This result emphasizes the importance of designing activities that are not only motivating, but also they are aligned with learning objectives. Comparing both courses, CA obtained an average score of 4/5, while MIT obtained 4.3/5. Both courses reflect a significant contribution, but MIT manifests a marginally higher evaluation, revealing a more favorable perception of the activity with respect to the academic objectives. This is attributable to the higher degree of academic maturity exhibited by MIT students.

In general, 55% of students affirmed that their oral communication skills have been strengthened after completing the activity, evidencing a positive impact on students' cross-cutting formation. Both courses demonstrated similar results in strengthening oral communication skills, despite the disparity in the number of participants and the different orientations of the activities: electrical circuit resolution in CA and understanding scientific texts in English in MIT. The general perception of an increase in motivation and participation, positively evaluated by 71% of students, indicates that the activity not only met academic objectives, but also generated a stimulating and committed educational environment. This result is essential, as motivation and active participation are key factors for the academic success. This aspect is highly relevant, as the lack of motivation and participation has been increasing since the end of the COVID-19 pandemic. In light of this result, a significant change is confirmed in the students' responses between the PRE-Q and POST-Q questionnaires regarding motivation and participation. It is also noteworthy that 71% of students would recommend maintaining the activity in future academic years, highlighting its potential in enhancing the learning experience. 69% and 79% of CA and MIT students, respectively, advocate for maintaining the activity in future academic years, with MIT showing a more pronounced preference, suggesting higher acceptance among third-year students.

On the other hand, 70% of students believe that student-generated multimedia content could be a useful resource for future students, as can be seen in Fig. 5. This supports the idea that the produced material has potential as an effective pedagogical tool. The implementation of the activity in MIT significantly highlights a higher recognition, 86%, of the utility of audiovisual content, indicating a greater appreciation of this modality in understanding scientific texts in English compared to electrical circuit resolution in CA, 65%.

Finally, regarding the teaching supervision during the activity implementation, 74% of students considered it "Very good" or "Good". This indicates that students value the quality of guidance provided during the activity's

TABLE 3. Statistical results corresponding to the final questionnaire (POST-Q).

Question	Restriction	CA	MIT	Overall results
How would you rate your overall experience with the activity?	Very good	33%	50%	37%
	Good	46%	43%	44%
	Fair	17%	7%	15%
	Poor	2%	0%	2%
	Very poor	2%	0%	2%
To what extent do you believe this activity contributed to your understanding of the academic objectives of the course?	Rate on a scale from 1 to 5, with 1 being "Not at all" and 5 being "A lot"	4/5	4.3/5	4.1/5
Do you think your oral communication skills have improved after completing the activity?	Yes	54%	57%	55%
	Fair	29%	36%	30%
	No	17%	7%	15%
Do you believe this activity increased your levels of motivation and participation in the course compared to other teaching methods?	Yes	69%	79%	71%
	Fair	25%	21%	24%
	No	6%	0%	5%
Would you recommend keeping this activity in future academic years?	Yes	69%	79%	71%
	Yes, but with some modification	25%	14%	23%
	No	6%	7%	6%
Do you consider that the student-generated multimedia content could be a useful resource for future students?	Yes	65%	86%	70%
	Fair	29%	7%	24%
	No	6%	7%	6%
Regarding my role as a reviewer of the videos made by peers:	I have made an effort to rate according to the rubric, providing comments on areas for improvement	67%	79%	71%
	I have only rated based on the overall impression it has given me	33%	21%	31%
How would you rate the teaching supervision during the activity?	Very good	27%	36%	29%
	Good	42%	57%	45%
	Fair	29%	7%	24%
	Poor	2%	0%	2%
	Very poor	0%	0%	0%
How would you rate the teaching performance overall in motivating the course?	Very good	44%	64%	48%
	Good	25%	36%	27%
	Fair	29%	0%	23%
	Poor	2%	0%	2%
	Very poor	0%	0%	0%

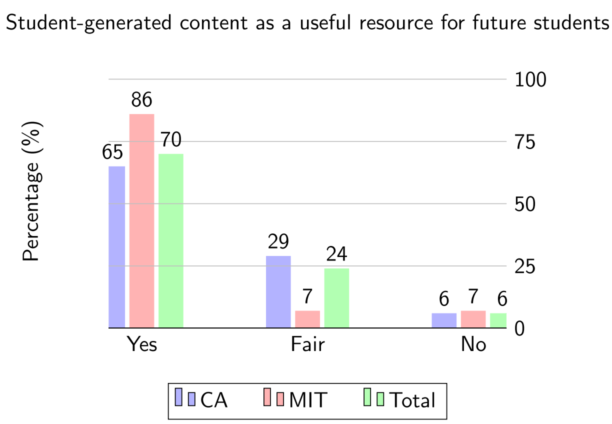


FIGURE 5. Bar diagram associated with statistical results related to the usefulness of multimedia content generated by students as a useful resource for future students.

development. Regarding teaching performance in motivating the courses, 76% rated it as "Very good" or "Good". This suggests that the teachers played an effective role in motivating students in the context of the activity, as can be seen graphically in Fig. 6.

D. IMPACT ON THE FINAL GRADE

In this section, an analysis of the impact of the proposed activity on the final grade of students in the final exam is carried out for both courses. Regarding the final grades obtained by the CA students, a total of 25 students attended the exam, and half of them completed the activity during the semester, while the other half chose not to participate. In relation to the group of students who performed the activity, 10/13 managed to pass the course, with two exceptional grades of 9.5/10 and 10/10. The average final grade of this group was 6/10 with a standard deviation value of 2.1, indicating consistency in the results. In contrast, in relation to the group of students who did not perform the activity, only 3/13 managed to pass the course, obtaining an average final grade significantly lower: 3.6/10 with a standard deviation value of 1.6. These results suggest that the activity had a positive and significant

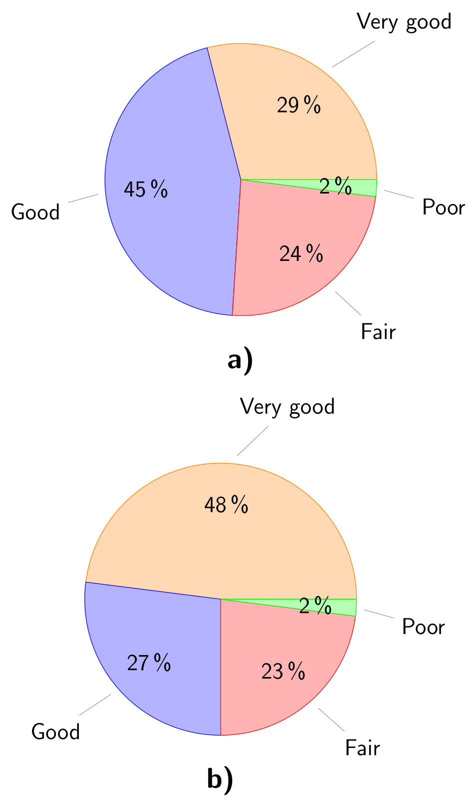


FIGURE 6. Total statistical results in relation to the a) teaching supervision and b) teaching performance during the implementation of the activity.

impact on the academic performance of the students who participated in it, contributing to the improvement of their final grades, and highlighting its relevance as part of the learning process. Therefore, it is concluded that the students who completed the proposed activity not only obtained higher grades compared to the group that chose not to participate, but also demonstrated a higher level of understanding of the academic content of the course. The creation of videos by students not only resulted in a more active and participative learning, but also facilitated the consolidation of key concepts.

Regarding the final grades obtained by the MIT students, out of the 21 students presented, all of them completed the activity during the semester. A total of 18/21 managed to pass the course, achieving an average final grade of 6/10 with a standard deviation value of 1.5, indicating an average academic performance and moderate variability. It is noteworthy that higher final grades were associated with students who produced the best videos, suggesting a high correlation between the quality of the activity and the performance in the exam.

It can be concluded that completing the activity has allowed the students to bring the course up to date, evidencing a more solid understanding of the teaching topics, which translated into a better performance in the final evaluation.

IV. CONCLUSION

In this paper, the implementation of an innovative active and collaborative learning method based on the creation of videos by the students in some of the courses belonging to the Degree in Electrical Engineering at the University of Málaga has been thoroughly explored. The initiative sought to revitalize student motivation and participation, offering a novel perspective on the teaching and learning process. At the same time, developing and/or strengthening soft skills such as oral communication, among others. Unlike the learning method in which the teacher is the one who creates the multimedia content and the students *learn by watching videos*, this study has presented a method in which the students themselves are the ones who develop the multimedia content and, hence, *they learn by making videos*.

On the one hand, the creation of academic multimedia content by students resulted in, according to the reported results, being an effective tool to promote motivation and participation, as well as understanding of both theoretical and practical concepts, with its corresponding impact on the final grades. Students were able to customize the content of their videos to fit their learning style and preferences, making it easier to understand concepts by approaching them from their own perspective. It is also concluded that the degree of maturity and responsibility of the students involved has a notable impact. On the other hand, both courses demonstrated similar results in strengthening oral communication skills, despite the differences in the nature of the activities. This finding suggests the versatility and applicability of the method in various academic areas.

Finally, the conclusions derived from this study provide valuable lessons for planning future activities and adapting pedagogical approaches. The continuous improvement of the educational process in higher education can directly benefit from the data reported in this paper, opening the door to new ways of promoting student motivation and participation.

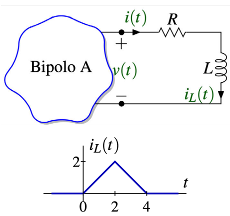
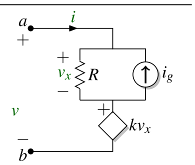
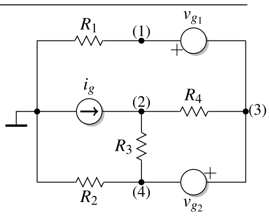
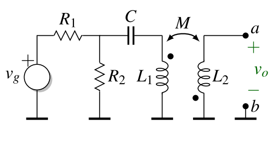
V. LIMITATIONS AND FUTURE DIRECTIONS

Based on the observations and comments provided by the students after completing the activity, which are omitted here, some improvements are identified for possible future implementations of the activity presented in the field of STEM disciplines with the aim of further strengthening and enriching the learning experiences. Thus, we identify the following improvements: a) Encouraging participation, for example, by implementing strategies like incentives, recognition, or friendly competitions to boost student participation in the activity. Cultivate an environment where participation is valued and rewarding, motivating more students to actively contribute to collaborative learning; b) Modifying the duration of the videos, for example, by considering to adjust the time limit for videos to allow for a more thorough explanation of concepts, ensuring all relevant aspects are covered adequately; c) Managing academic load, for example, by addressing concerns about excessive academic workload impacting the quality and originality of the projects; d) Addressing the variability in peer assessment, for example, by tackling the differences in peer assessment among groups, particularly in MIT, as well as identifying factors and developing strategies to enhance consistency in perceived work quality; and e) Implementing continuous feedback mechanisms, for example, by establishing a feedback system to gather input from students after each activity implementation. Use this feedback to iteratively improve the design and execution of future activities, ensuring ongoing alignment with student needs and expectation.

APPENDIX

In Table 4, four typical exercise statements from the CA exercises list associated with each of the didactic topics are illustrated as examples, where the students are required to create a video with the solution to the exercise, as specified in Section II-B.

TABLE 4. Four typical exercise statements from the CA exercises list associated with each of the didactic topics.

<table>
<tr><th>Exercise statement</th><th>Figure</th></tr>
<tr><td>In the right Figure, obtain and graphically represent the voltage $v(t)$, knowing that $i_L(t)$ is the current that circulates through the inductor, L. (Academic data: $R = 3\ \Omega$, $L = 6$ H). Also, explain the energetic behavior of the electrical circuit, specifying the time intervals in which Bipole A absorbs and delivers energy.</td><td>
</td></tr>
<tr><td>In the right Figure, determine the voltage-current behavior at the terminals a and b of the bipole, drawing a simpler equivalent circuit, by employing the Thèvenin and Norton theorems, and calculating the parameters v_{ca}, i_{cc}, and R_{eq}.</td><td>
</td></tr>
<tr><td>In the right Figure, obtain the equations system that allow you to calculate all nodal voltages, applying the nodal analysis technique.</td><td>
</td></tr>
<tr><td>In the right Figure, knowing that the electrical circuit is working in sinusoidal steady state, obtain the frequency response of the circuit defined as $H(j\omega) = \overline{V}_0/\overline{V}_g$ as a function of its parameters. Also, determine the voltage $v_0(t)$ for the following academic data: $v_g(t) = 5\cos\left(2 \cdot 10^6 \pi t\right)$ V, $R_1 = 10\ \Omega$, $R_2 = 10\ \Omega$, $L_1 = 1.591\ \mu H$, $L_2 = 3.183\ \mu H$, $M = 0.796\ \mu H$ and $C = 31.8$ nF.</td><td>
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</table>

On the other hand, by way of example, two of the articles selected to do the activity in MIT are briefly described. Furthermore, in order to help in the task of understanding the article, some questions associated with each article are provided to guide the content of the video. In this way, one of the selected article is titled "*The JPEG AI Standard: Providing Efficient Human and Machine Visual Data Consumption*" [54]. This article provides insights into leveraging artificial intelligence within the JPEG (Joint Photographic Experts Group) image compression standard. Although aspects of artificial intelligence are not directly covered during lectures, this article will enable students to explore how these emerging technologies significantly impact the efficiency of image compression, thus connecting acquired knowledge with innovative trends in multimedia technology. The following questions serve as a guide to addressing the creation of the video:

1) Q1: What is JPEG AI and what is its purpose? It is important to understand in detail what JPEG AI entails, its structure, and its specific function in the context of image compression and the application of artificial intelligence.
2) Q2: How does JPEG AI differ from conventional image coding standards? What does artificial intelligence contribute?
3) Q3: How is JPEG AI expected to enhance image compression and visualization for both humans and machines? What applications will benefit from JPEG AI?
4) Q3: What are the technical features and requirements of JPEG AI?

Another article is titled "*Versatile Video Coding explained. The future of video in a 5G world*" [57]. This article provides an overview and description of the latest video compression standard: VVC/H.266. In addition, it allows the student to consolidate and expand the knowledge acquired in class about the HEVC (*High Efficiency Video Coding*) or H.265. By exploring VVC/H.266, students will have the opportunity to examine emerging technologies in the field of video compression, making connections between previously taught concepts and the latest trends. The following questions serve as a guide to approach making the video.

1) Q1: How does VVC work? What benefits does it provide compared to previous video compression standard?
2) Q2: What is immersive video?
3) Q3: What is low-delay video encoding and why can it be so interesting?
4) Q4: How is it different from its HEVC predecessor?

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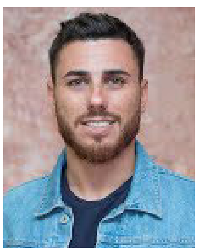

RUBÉN BOLUDA-RUIZ was born in Málaga, Spain, in 1986. He received the B.Sc. and M.Sc. degrees in telecommunication engineering (electronics and communications) and the Ph.D. degree in electrical engineering from the University of Málaga, Málaga, in 2012, 2014, and 2017, respectively.

From 2010 to 2013, he was a Software Engineer in the telecommunication industry. In 2016, he was a Visiting Researcher with the Department of Electrical and Computer Engineering, McMaster University, Hamilton, ON, Canada. From October 2017 to December 2019, he was a Postdoctoral Research Associate with the Electrical and Computer Engineering Program, Texas A&M University at Qatar. From January 2020 to May 2021, he was a Postdoctoral Researcher with the Communications Engineering Department, University of Málaga. Since May 2021, he has been an Assistant Professor with the Communications Engineering Department, University of Málaga. He has authored/co-authored 50 journal and conference publications. His current research interests include theory and its application to design and performance analysis of terrestrial and underwater free-space optical (FSO) communication systems with current emphasis on channel modeling, multiple-input/multiple-output (MIMO) systems, and physical layer security aspects.

Dr. Boluda-Ruiz is an active reviewer of various IEEE and Optica (formerly OSA) top journals. He was a recipient of the Best Ph.D. Thesis in Electrical Engineering (Extraordinary Doctorate Award) by the University of Málaga, from 2017 to 2018, the Best Ph.D. Thesis in Electrical Engineering in the XVI Night of Telecommunications by the Agencia Andaluza de Ingenieros de Telecomunicación (AAIT), in 2018, the TAMUQ Research Excellence Award, in 2018, and the Exemplary Reviewer Certificate of 2021 by IEEE TRANSACTIONS ON COMMUNICATIONS.

PEDRO SALCEDO-SERRANO was born in Granada, Spain, in 1997. He received the B.Sc. and M.Sc. degrees in telecommunication engineering (acoustic and communications) from the University of Málaga, Málaga, Spain, in 2019 and 2020, respectively, where he is currently pursuing the Ph.D. degree with the Communications Engineering Department. His current research interests include information theory and its application to design and performance analysis of underwater optical wireless communication systems with a current emphasis on underwater channel modeling.

BEATRIZ CASTILLO-VÁZQUEZ was born in Madrid, Spain, in 1971. She received the M.Sc. and Ph.D. degrees in electrical engineering from the University of Málaga, in 1994 and 1999, respectively. She joined the Department of Communications Engineering, University of Málaga, in 1995, where she currently holds the position of an Associate Professor. Her primary research interests include optical wireless communications, including free-space optics (FSO), underwater optical wireless communications (UOWC), channel modeling, relay/multihop communications, and physical layer secrecy issues.

ANTONIO GARCÍA-ZAMBRANA was born in Málaga, Spain, in 1970. He received the M.Sc. and Ph.D. degrees in electrical engineering from the University of Málaga, in 1994 and 1998, respectively. Following his education, he joined the Department of Communications Engineering, University of Málaga, in 1994. He currently holds the position of a Full Professor with the Department of Communications Engineering, University of Málaga. He has made significant contributions to the field of optical wireless communications. His primary research interests include encompassing various aspects, such as free-space optics, underwater optical wireless communications, channel modeling, relay/multihop communications, and physical layer secrecy issues.

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