IMPLICATIONS OF USING DISSEMINATION VIDEOS AS A DIDACTIC RESOURCE IN STEM EDUCATION

PhD Thesis
Compendium of Publications

Doctor of Philosophy
in Education

by
Rubén Lijó Sánchez

under the supervision of
José Juan Castro Sánchez
Eduardo Gregorio Quevedo Gutiérrez

Universidad de La Laguna

May 2024

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San Cristóbal de La Laguna, May 2024

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Deposit date: May 2024.

More information about the author of this Ph.D. thesis and his research is available at rubenlijo.com

Progress of any kind is only achieved by those able to stand on the shoulders of giants. They constitute the foundations of our intellectual growth, our personal developments, and or contributions to society.

This doctoral thesis is dedicated to Miguel Sánchez Herrera and Alicia Mª Sánchez Rodríguez, the best grandfather and mother one could ask. They have always been my personal guiding giants.

Abstract

Studies related to Science, Technology, Engineering, and Mathematics (STEM) present specific challenges for their students, which were emphasized during the Emergency Remote Learning (ERL) scenario due to the COVID-19 pandemic in 2020. These types of learning challenges are fundamentally related to the wide presence of abstract concepts in their subjects and the difficulty in establishing connections between the different conceptual areas that make up their degrees.

Audiovisual resources have proven helpful as pedagogical support in mitigating these drawbacks. However, their adequate creation by educators requires an advanced level of digital competence and a significant investment of time and resources. Nonetheless, public dissemination audiovisual materials, widely available online, can help fill this gap. This doctoral thesis focuses on the pedagogical value of STEM dissemination resources based on metrics from current literature and on the implementation of strategies for their proper integration into formal education.

Through a methodology based on a mixed methods design, the users' perception of one of the leading YouTube channels for STEM dissemination in Spanish about its potential educational use has been evaluated (N1=912). Based on this information, a content strategy has been developed that is aligned with its integration into subjects of the Electrical Engineering BSc. The objective was to reinforce abstract concepts related to physics and mathematics, and it was used during three academic years in a subject of the degree, covering before, during, and after ERL (N2=157). Finally, after the creation of such a new line of content on the channel, directly focused on its pedagogical integration, a complete analysis of the channel's metrics grouped in the published videos as sample (N3=147) has been carried out, with the information obtained through the 4,268,071 views achieved in the channel. A categorization has been set between contents with a dissemination intention and contents with an educational intention. This dual purpose allows for evaluating the potential educational use of dissemination channels and understanding its users' behavior and interests.

This research shows the broad potential of integrating multimedia dissemination resources in the classroom. An increase in the motivation and interest of students in STEM-related subjects has been quantified, together with an excellent perception of the main metrics that allow evaluating the adequacy of multimedia resources for educational use, both in terms of content and audiovisual quality. Moreover, it can be observed how an adequate integration of this type of resources in ERL situations can contribute to mitigate the decline in academic performance and improving the perception of teaching quality in these types of forced learning situations.

These results show the current window of opportunity represented by this bidirectional path that connects education with dissemination. On the one hand, it reinforces that the teaching staff in the formal education of STEM subjects can benefit from the positive aspects of using these types of materials. On the other hand, it establishes a framework that encourages dissemination content creators to consider new strategic lines of work, primarily focused on the curricular alignment of their contents. This would increase such resources' availability and usability in the educational field.

Based on these ideas, future research will study the connections between dissemination resources and education, and the digital competences of educators and students. Moreover, the use of educational technologies for the didactics of mathematics will also be explored, as this discipline represents the greatest exponent of abstraction.

Keywords: conceptual learning, didactic videos, digital competences, distance learning, educational technologies, learning difficulties, STEM education, video-based learning.

Resumen

Los estudios relacionados con Ciencia, Tecnología, Ingeniería y Matemáticas (STEM, por sus siglas en inglés) presentan retos específicos para sus estudiantes, que se vieron enfatizados durante la Enseñanza Remota de Emergencia (ERL, por sus siglas en inglés) debido a la pandemia del COVID-19 en 2020. Estos retos están fundamentalmente relacionados con la amplia presencia de conceptos abstractos en sus temáticas, así como con la dificultad para trazar conexiones entre las distintas áreas conceptuales que componen sus titulaciones.

Los recursos audiovisuales han demostrado ser de utilidad como apoyo pedagógico en la mitigación de estos inconvenientes. Sin embargo, su adecuada creación por parte del docente requiere de un nivel avanzado de competencia digital, así como de una gran inversión de tiempo y recursos. No obstante, los materiales audiovisuales de divulgación disponibles en internet pueden ser útiles para cubrir este vacío. En esa línea, esta tesis doctoral se centra en el estudio del valor pedagógico de recursos de divulgación STEM a partir de métricas consensuadas en la literatura actual.

Mediante una metodología basada en un diseño de método mixto, se ha evaluado la percepción de los usuarios (N1=912) de uno de los principales canales de YouTube de divulgación STEM en español sobre su potencial valor educativo. A partir de esta información, se ha desarrollado una estrategia de contenidos alineada con su integración en asignaturas del Grado en Ingeniería Eléctrica. El objetivo consistía en reforzar conceptos abstractos relacionados con las áreas de Física y Matemáticas, y se empleó empleada durante tres cursos académicos en una asignatura del grado, cubriendo el antes, durante y después de la ERL (N2=157). Finalmente, tras la creación de esta nueva línea de contenidos en el canal, directamente enfocada a su integración pedagógica, se ha realizado un análisis completo de las métricas del canal agrupadas en la muestra de vídeos publicados (N3=147), con la información obtenida a través de las 4.268.071 visitas recibidas en el canal. Se ha establecido una categorización entre contenidos de intencionalidad divulgativa y contenidos de intencionalidad educativa. Esta intención dual permite evaluar el potencial uso educativo de canales de divulgación, así como entender el comportamiento y los intereses de sus usuarios.

Los resultados de esta investigación ponen de manifiesto el amplio potencial de la integración de recursos multimedia de divulgación en el aula. Se ha cuantificado un aumento de la motivación e interés del alumnado por las materias relacionadas con las disciplinas STEM, así como una excelente percepción sobre las principales métricas que permiten evaluar la adecuación de los contenidos multimedia para uso educativo. Además, se ha podido apreciar cómo una adecuada integración de este tipo de recursos en

situaciones de ERL puede contribuir a mitigar el decaimiento del rendimiento académico, así como mejorar la percepción sobre la calidad docente.

Estos resultados ponen de manifiesto la actual ventana de oportunidad que supone este camino bidireccional entre la educación y la divulgación. Por un lado, se refuerza que los docentes de materias STEM puedan aprovechar los beneficios de este tipo de recursos. Por otro lado, se establece un marco capaz de fomentar que los creadores de contenido de divulgación consideren nuevas líneas estratégicas de trabajo especialmente dirigidas a la alineación curricular de sus contenidos. Esto daría lugar a un aumento en la disponibilidad de recursos y en su utilidad para el ámbito educativo.

Tomando este testigo, las futuras líneas de investigación profundizarán en el estudio de las conexiones entre los recursos de divulgación y la educación, así como en las competencias digitales para educadores y alumnos. Además, también se explorará el uso de las tecnologías educativas para la didáctica de las matemáticas, ya que esta disciplina representa el máximo exponente de la abstracción.

Palabras clave: aprendizaje conceptual, competencias digitales, educación a distancia, educación STEM, métodos audiovisuales en pedagogía, problemas de aprendizaje, tecnología educativa, vídeos educativos.

About the Author

My academic background combines the fields of Engineering, Dissemination, and Education. After a central dedication to Electrical Engineering for more than eight years, combined with an intense commitment to Dissemination and Education activities, I am currently working at Hitachi Energy as Global Training Coordinator. In addition, since 2019, I have collaborated as an external professor in the degree "University Expert in Digital Competences for Educators" at the *Universidad de Las Palmas de Gran Canaria* (ULPGC). Moreover, since 2023, I have collaborated with the Area of Didactics of Mathematics at the ULPGC through a *Venia Docendi*. My research interests are oriented to Educational Sciences and specifically related to the areas of Didactics of Mathematics, Educational Technology, Digital Competences, and STEM Education (Science, Technology, Engineering, and Mathematics).

I have developed my professional career mainly in the private sector, where I have worked at Hitachi Energy as an Engineering and Training Consultant (Oct.20 - Feb.24) and Global Training Coordinator (Feb.24 - today). I have also worked as an Electrical Engineer at IDOM (Feb.19 - Oct.20), Ayesa (Mar.18 - Feb.19) and the Oceanic Platform of the Canary Islands (Feb.17 - Sep.17). Moreover, I have complemented this professional activity with an intense dedication to STEM Dissemination and Education activities since 2011, providing consulting and training services, as well as creating national organizations for the dissemination of scientific culture such as *Hablando de Ciencia*[1], *Scenio*[2], or *Vector Divulgación*[3]. I have owned an engineering dissemination YouTube channel since 2017 called *Sígueme la Corriente*[4], with over 170.000 subscribers and 5.500.000 views as of 1st May 2024. My dissemination activity has been recognized with three 1st awards and two honorable mentions at the Spanish *Ciencia en Acción* national awards.

I have been an Electrical Engineer since 2015 by the ULPGC (special mention of the Spanish Wind Energy Association for my final degree project), with a specialization stay at the *Universitat Politècnica de Catalunya* (UPC). I continued my education later with a master's degree in Industrial Technologies at the ULPGC, which I finished in 2017 (final master's thesis semifinalist in the 9th Edition of the EDPR University Challenge). The doctoral thesis presented in this document is the culmination of my PhD studies in Education at the *Universidad de La Laguna* (ULL).

[1] https://hablandodeciencia.com (Accessed 01/05/2024).
[2] https://scenio.es (Accessed 01/05/2024).
[3] https://vectordivulgacion.com (Accessed 01/05/2024).
[4] https://youtube.com/SiguemeLaCorriente (Accessed 01/05/2024).

Acknowledgments

First and foremost, I would like to express my deepest gratitude to my thesis directors, Dr. Eduardo Quevedo and Dr. José Juan Castro. Their guidance, support, and mentorship have been invaluable throughout this journey. Their expertise has been crucial for developing this multidisciplinary doctoral thesis, along with their combined specialized backgrounds in Developmental and Educational Psychology, Didactic of Mathematics, Educational Technology, and STEM Dissemination. Their knowledge and dedication to this research have been a driving force behind this work.

I would also like to sincerely thank Dr. Ricard Horta, whose substantial contributions to my research have been instrumental in shaping this thesis. His academic background in Electrical Engineering has been essential in defining the didactic materials, case studies, and classroom interventions. His experienced insights and collaboration have deeply enriched this work.

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On the institutional level, I would like to express my gratitude to the organizations that have supported me throughout my doctoral journey. First, I want to acknowledge the *Universidad de La Laguna*, where I have developed my doctoral studies. Their financial support enabled me to attend an international conference in Colombia, which was instrumental to the research presented in these pages and an unforgettable experience. I am also profoundly grateful to the *Universidad de Las Palmas de Gran Canaria*, the institution my directors belong to. Their complementary financial and institutional support has been invaluable. Their commitment to disseminating my research results has significantly contributed to the reach and impact of this thesis. Moreover, I would like to thank the *Universitat Politècnica de Catalunya*. They generously opened their doors for me to run relevant case studies for my research and committed to disseminating the results. Lastly, I am grateful to those in Hitachi Energy who have allowed me to progress on the training and research path. Manuel Jesús López, Susana Ubierna, Helena Martínez: Thanks for your support in a not always favorable context.

Furthermore, I would like to thank the contributions of other science disseminators, academics, educators, and journalists who have taken the time and effort to discuss the implications of science communication and dissemination. The definition of the mission and boundaries of public dissemination and its relationship with other mechanisms for knowledge communication is still a topic for debate and discussion. This first effort starts an exciting path to be continued. Dr. Javier Santaolalla, Dr. Maite Iriondo, Dr. Laura Toribio, Dr. Ricard Horta, Dr. David Romero, Ignacio Crespo, Santiago Campillo, Simón Perera, Jorge Hernández, Marcial González: thanks for contributing to these reflections.

In the personal sphere, I am filled with gratitude for the unwavering support of my family. To my mother, Alicia, and my grandparents, Miguel and Dorita. Thank you for your constant love, encouragement, and belief in this journey. Your unconditional support has not only been a source of strength but also a comforting refuge during challenging times. I would also like to thank my godfather, David, for his academic guidance and counsel. His belief in my abilities and trajectory, and how to merge them with the academic field, was the initial spark that motivated me to take this journey. A special mention is also made to Raquel Polo, whose patience and understanding have been a strong support throughout this journey. She has shared my struggles, celebrated my successes, and provided a listening ear when I most needed it. Also, thanks to my brother, Breogán, who has put his skills in place to offer invaluable advice in analyzing and illustrating demographic and geographic information. And, last, to Ayla and Luar, whose innocent gaze has reshaped my vision of the world and what matters in life.

My deepest thanks are also to Marcial González. Together, we have shouldered the heavy backpack of stress and uncertainty that comes with actively working in industry, academia, and dissemination. Our conversations, always reflecting our shared experiences and aspirations, have made this path less daunting and more rewarding. Special thanks are also to Santiago Campillo and our never-ending tandem. Thanks for the uncountable discussions attempting to understand dissemination and its boundaries clearly. This doctoral thesis started with those shared moments. I have no doubts that the path we started is still far from its end (no matter how many resting stops we take). My thanks are also to Ignacio Crespo, whose inquisitive mind and sharpened comments have also provided helpful counsel, always pointing in the right direction with surgical precision. I would also like to thank Jorge Hernández for our endless discussions on pursuing horizontal learning. Philosophy, psychology, economy, health… Even coffee! This is the real *gofio* for the mind. Finally, I want to thank Tinta: the *perito* for my engineer. Always side by side, as a companion I had never even dreamed of having.

Ultimately, I would like to thank myself for not quitting and persevering even when all signs pointed in the opposite direction. Thanks for standing up despite

those who did not support or understand this path. Thanks for not needing the presence of those who never wanted to be. And thanks for believing in the power of changing and evolving. Everything seems complicated before it becomes easy. *Al golpito.*

In conclusion, I am profoundly grateful to all who have contributed to this journey. Your collective influence has shaped not only this work but also the researcher and person I have become. Thanks!

Contents

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Abbreviations and Relevant Concepts

CLT	Cognitive Load Theory.
CoI	Community of Inquiry.
CTML	Cognitive Theory of Multimedia Learning.
DigCompEdu	European Framework for the Digital Competence of Educators.
Dissemination	This research uses it for public dissemination (section 0.2).
DOI	Digital Object Identifier
Edutuber	Educational content creator on YouTube.
ERL	Emergency Remote Learning.
ESEIAAT	Escuela Superior de Ingenierías Industrial, Aeroespacial y Audiovisual – UPC.
ICT	Information and Communications Technologies.
IEEE	Institute of Electrical and Electronics Engineers.
MOOC	Massive Online Open Courses.
OS	Operating System
PBL	Problem-Based Learning.
PjBL	Project-Based Learning.
RQ	Research Question.
RO	Research Objective.
ROX.QY	Research Question Y belonging to Research Objective X.
SDG	Sustainable Development Goals.
SEEQ	Students' Evaluation of Educational Quality
STEAM	Science, Technology, Engineering, Arts and Mathematics.
STEM	Science, Technology, Engineering and Mathematics.
TBL	Thinking-Based Learning.
TPACK	Technological Pedagogical Content Knowledge.
ULL	Universidad de La Laguna.
ULPGC	Universidad de Las Palmas de Gran Canaria.
UPC	Universitat Politècnica de Catalunya.
UN	United Nations.
UNESCO	United Nations Educational, Scientific, and Cultural Organization.
VBL	Video-Based Learning.

0

PREFACE

EXPLORING THE BOUNDARIES OF DISSEMINATION

> *We've arranged a society based on science and technology, in which nobody understands anything about science and technology […] Science is more than a body of knowledge. It's a way of thinking. A way of skeptically interrogating the universe with a fine understanding of human fallibility".*

Carl Sagan
Extract of his last interview, on the 27th of May 1996

Note from the author: This preface aims to serve as a reflexive introductory space; a place to share the debates and open questions that led to the development of this doctoral thesis. This preface does not intend to present scientific results or facts. Instead, it aims to openly ponder the existing debate about the role and boundaries of public dissemination and its interconnections with other mechanisms for knowledge communication, such as academic dissemination, education, or journalism. It also aims to provide a descriptive definition of the concept of dissemination that will be used in this doctoral thesis.

0. Preface:
Exploring the boundaries of dissemination

Human beings are born with an intrinsic capacity for learning (Beard, 2018). This feature, provided by the ways of evolution, has allowed our species to develop in unimaginable ways, from the essential skills that keep us alive to the unprecedented technological revolution of the present.

When thinking about the constituting elements defining each one of us, I was inspired by the following reasoning[5] presented in the dissemination book *How We Learn: the new science of education and the brain* (Dehaene, 2021).

The formation of every human starts with a code composed of twenty-three chromosomes containing three billion pairs of molecules A, C, G, and T (adenine, cytosine, guanine, and thymine). This represents, when translated to information, a codification of two bits for each of the four letters of the genome (00, 01, 10, and 11), leading to a total of six billion bits. By translating this to the bytes used in computational systems (composed of sequences of eight bits), the human genome would be equivalent to about 750 megabytes of information (which can be stored in an old-fashioned CD-ROM).

This is enough to be initially stored in a single fertilized egg, acting as if it were the installer of an Operating System (OS). In an adequate environment, such fertilized egg will develop our whole body, as the computer where such OS will run. Therefore, it will be able to create an entire body containing one brain with a computing capacity of over one hundred terabytes (Dehaene, 2021). This is a hundred thousand times more than the information initially stored in our genome. And this newly developed brain will be ready to learn. Therefore, learning becomes necessary for our complete development, as it would not be possible to store such a high amount of information, plus the recipe for our body, only in the fertilized egg where it all began. Similarly to our computers being able to install programs that enhance their specific capabilities, our brains are wired with such an intrinsic ability to develop and

[5] Note that this is not intended to represent a scientifically accurate and fully developed reasoning, but rather a brief introductory reflection of the role of learning (which is not exclusive for our species).

learn new knowledge and skills. This can be done by simple observation and replication or through our abstraction capability.

According to Dehaene (2021), learning consists of four fundamental pillars: attention, active engagement, error feedback, and consolidation. Figure 1 shows a schematic view of these pillars.

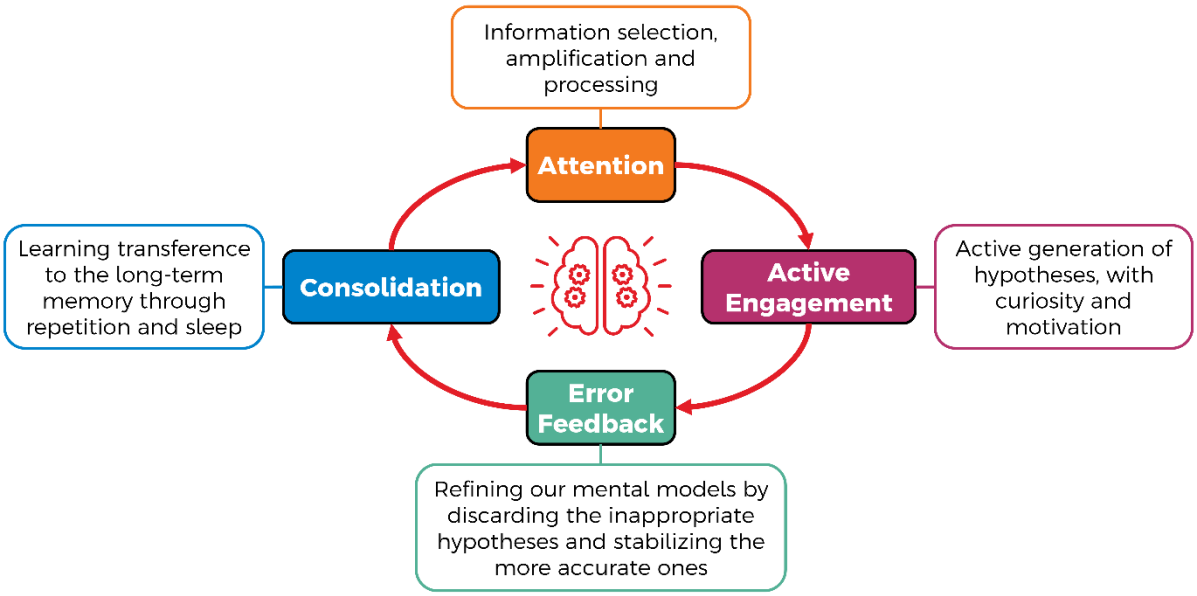


Figure 1. Schematic view of Dehane's four pillars of learning.

1. The first one, attention, emphasizes that effective learning begins with showing an interest in the information received as input. Without focused attention, learning is impossible. In educational settings, teachers play a crucial role in capturing students' attention through engaging methods such as thought-provoking questions, variations in their tone of voice, or encouraging interaction. Clear explanations about what to focus on, prioritizing information, and repetition are essential for adequately gaining the student's attention. Thus, our attention is a selective filter, focusing on specific information while letting other details pass by.

2. Then active engagement is crucial for retention. Students should ask questions, formulate hypotheses, and apply what they have learned to truly understand the information they receive. Mere passive listening is ineffective for learning, and this intellectual effort should not be dismissed when trying to anchor knowledge in our brains and memory. An active approach contributes to effective learning.

3. Error feedback comes next, emphasizing the role of errors in the learning process. When we understand the reasons for those errors, they are crucial contributors to learning effectively. Constructive feedback helps identify

mistakes and correct them. In this sense, our brains are wired to operate following a closed cycle prediction and error correction, leading to successive adjustments that facilitate learning.

4. Finally, knowledge consolidation is the fourth pillar of learning. This process is fostered by repetition and sleep, allowing our brain to solidify what we have learned. Therefore, sleep plays a crucial role in memory formation, retention, and consolidation. In other words, sleeping is essential for effective long-term learning.

This learning process allows us to effectively learn from the information we receive through various knowledge communication methods. From ancestral oral transmission to the written word and evolving to more modern and structured mechanisms, communication allows individuals and societies to share their knowledge and prosper.

0.1 Conjoined Ellipses of Knowledge Communication: The Four Mechanisms

Knowledge, as the cornerstone of individual and collective advancement (Bindé, 2005), is generated through the processing of information that can be transferred in an appropriate representation to an adequate activity (Simske, 2019). There are several types of knowledge, such as basic knowledge, typically acquired spontaneously, without a methodology, just because we are alive and in contact with our surroundings; technical knowledge, which is dependent on certain social structures and requires specialized and thorough methodology; and critical knowledge, coming from a rigorous methodology with logical coherence that is based on observation and deep reflection (Di Marco Morales, 2015). This is the case with scientific or philosophical knowledge.

Critical knowledge is primarily generated through rigorous observation, research, and reflection. Once available, it should be communicated and transferred to peers and society. Figure 2 presents a Venn diagram that illustrates this thesis' proposal for structuring the mechanisms for knowledge communication. It represents the Conjoined Ellipses of Knowledge Communication: academic dissemination, journalism, education, and public dissemination.

As represented in Figure 2, these four mechanisms also overlap in several common spaces. The following subsections will elaborate on each mechanism and its interconnections. This classification intends to define and delimit the

concepts that this doctoral thesis refers to so that it can later focus on the specific case of public dissemination and its interconnection with education.

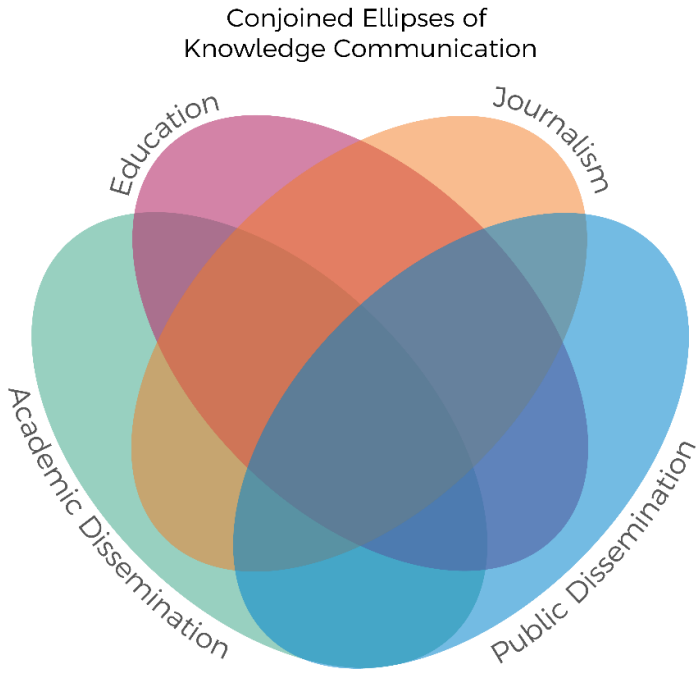


Figure 2. Conjoined Ellipses of Knowledge Communication: Proposed Venn diagram.

Academic dissemination

Once new scientific knowledge is generated through research, academic dissemination becomes a critical mechanism for the transmission of knowledge within the academic community and beyond (Ross-Hellauer et al., 2020). Academic dissemination is the act of sharing research results with peers through academic articles and other forms of academic communication (NIHR, 2019).

The primary method of academic dissemination is publishing papers in academic journals. These peer-reviewed journals promote the validity and quality of the research and also serve as a platform for researchers to share their findings with the global academic community so that they are reproducible[6] and replicable[7]. Conferences and seminars are also standard methods by which researchers can present their work. These gatherings provide

[6] Reproducibility: obtaining consistent results using the same data as the original study.
[7] Replicability: obtaining consistent results using new data or new computational results to answer the same scientific question.

an opportunity to discuss new findings, receive feedback, and engage in scholarly debates that often foster collaboration and networking. Academic books also play a crucial role in academic dissemination, providing a structured and comprehensive analysis of a particular subject, usually diving into it with a depth and breadth that cannot be achieved in singular journal or conference articles.

Once the research has been published, academic and social networks such as ResearchGate and Academia.edu have emerged as significant tools for academic dissemination. These platforms allow scientists to share their research, receive feedback, engage in discussions, and collaborate with peers worldwide. Institutional repositories, where universities and research institutions archive and make available the outputs of their researchers, are also a formal way to disseminate research results.

Moreover, the publication of preprint archives is gaining popularity among researchers. This allows them to share their findings with peers before they undergo a peer review process for formal publication. This will enable them to obtain feedback that would enhance the final version of the paper and increase its visibility and citations during the review and publication phases.

Academic dissemination involves all the practices with which researchers share their results with peers. These methods ensure the knowledge generated is shared, scrutinized, and built upon. In this regard, the open access movement is also advocating for free and unrestricted access to research outputs, allowing anyone with internet access to read the published article and, thereby, increasing the reach and impact of research (Björk, 2017). This culture of openness and collaboration allows continuous learning within the academic community, as well as an easier transfer of the knowledge generated to society through other complementary mechanisms (Allen & Mehler, 2019).

Education

Education is usually categorized into formal education, non-formal education, and informal education learning (UNESCO, 2012)[8]. This subsection intends to define their scopes briefly.

Formal education is a traditional, direct, and regulated form of knowledge communication. It consists of the systematic instruction of knowledge from teachers to students in educational institutions through specific regulated

[8] According to the International Standard Classification of Education (ISCED) in its latest version from 2011.

curricula (Johnson & Majewska, 2022). Completing formal education often leads to degrees, diplomas, or certificates that validate a person's knowledge and skills.

> "Formal education is the highly institutionalized, chronologically graded, and hierarchically structured "education system", spanning lower primary school and the upper reaches of the university", Coombs and Ahmed (1974).

The knowledge generated from research is considered for its progressive integration into the educational curriculum. This curriculum is then taught in schools, colleges, and universities, ensuring that students are equipped with the latest and most relevant findings and developments in various fields of knowledge. Teachers, professors, and other educators play a pivotal role in this process, as they not only impart knowledge but also stimulate curiosity and critical thinking.

The educational institutions provide a conducive environment for knowledge transmission, offering a space where ideas can be discussed, debated, and understood in depth. The libraries, laboratories, and digital platforms within these institutions serve as knowledge repositories, facilitating easy access to vast information. Furthermore, education also involves the practical application of knowledge facilitated through laboratory experiments, field trips, internships, or projects that allow students to experiment their knowledge in real-world situations.

Non-formal education shares some characteristics with formal education, as it is also institutionalized, intentional, and planned by educational providers. However, its primary role is to complement or supplement formal education within the broader context of lifelong learning (UNESCO, 2012). It aims to ensure universal access to education, addressed to people of all ages, regardless of their educational background. In that sense, non-formal education does not necessarily adhere to a continuous pathway. It may consist of short-duration programs, workshops, or seminars.

Finally, informal education is the process of intentional learning that is voluntary to each individual but is not institutionalized. Unlike formal or non-formal education, informal learning lacks strict organization and structure (UNESCO, 2012). It encompasses a wide range of activities that take place in various contexts, such as family, workplace, local community, and daily life. Individuals engage in informal learning on a self-directed, family-directed, or socially-directed basis.

Like formal and non-formal education, informal learning differs from incidental or random learning, which occurs during day-to-day activities without specific educational intent. This frontier between informal and

incidental learning is often where individuals learn from journalism or public dissemination resources. Either with an informative purpose or as a cultural entertainment product, both communication mechanisms can provide a learning experience without being its primary intention.

Journalism

Journalism is also a traditional form of communicating knowledge to society with informative purposes (Splendore, 2022), related to relevant topical issues. It involves producing and distributing informative content, bridging events, facts, ideas, and people, and providing society with easy-to-access information to understand the world.

Journalism is usually focused on a social purpose, shaped by different approaches. It can be focused on reporting topical issues, aiming to present information about events to allow the public to be informed and build up their own opinions. Investigative journalism also aims to expose corruption, injustice, or wrongdoing, contributing to transparency and accountability. In this sense, it also seeks to scrutinize those in positions of authority, whether in government, business, or other institutions. By systematically questioning decisions, policies, and actions, journalism is intended to hold power accountable in front of society. Finally, it aims to serve as a source of information through well-researched articles, interviews, and reports. It provides context, analysis, and diverse perspectives for topical issues, allowing the public to form informed viewpoints.

Therefore, journalism communicates knowledge with an informative purpose, generally linked with relevant topical issues and with a social aim (Chadwick, 2019). Conceptually, it helps providing local, national, and international information hubs that keep society updated with recent events, foster discussions, and debate. Ultimately, journalism intends to report on culture and contribute to it, shaping cultural narratives and engaging with artistic expressions. In an ideal execution of the profession, journalism should also facilitate democratic processes by enabling campaigning, debating, voting, and extracting accountability.

However, journalism can also manipulate the information people are exposed to, facilitate targeted advertising, or increase polarization. The scarcity of resources in traditional media, together with their competition with social media for attention and clicks (fundamental for earnings through advertisement), has also conditioned the quality of the final product that journalism can deliver (Arroyas Langa, 2011; González Férriz, 2023; Pérez Latre,

2022). Such scarcity of resources has made journalistic work more precarious and drastically reduced the number of specialized journalists working for traditional mass media (García López, 2023; Pérez Latre, 2022). This implies that general journalists, frequently exposed to multitasking and work overload, take on specific topics such as science, economy, politics, or culture. This situation limits an adequate dedication to contrast information and contextualize it effectively (Pérez Latre, 2022; Sáinz Peña, 2013). Therefore, it becomes necessary to restructure journalism and the way it operates so that the traditional media can guarantee that their activity fulfills the expected mission of the journalistic activity (Diezhandino Nieto, 2012; González Férriz, 2023; Pérez Latre, 2022).

Meanwhile, in such a journalistic landscape, which brings credibility into question the public must be able to contrast the sources and verify their veracity before creating an opinion or adopting what is received as their own.

Public dissemination

Public dissemination is a powerful mechanism for communicating knowledge to society. It involves using various platforms, formats, and strategies to communicate scientific findings and other knowledge to a non-specialist audience.

Even though the concept of dissemination initially resorts to traditional formats such as books or documentaries, it represents a wide variety of products and activities. These formats can be public lectures, science festivals and fairs, social media, blogs, videoblogs or podcasts, for example. There are also other public dissemination approaches that intend to present the most engaging version of knowledge communication benefitting from unconventional formats such as comics, board games, or even comedy monologues[9].

Moreover, with this variety of formats, several scopes and purposes can be addressed. Public dissemination is a form of cultural entertainment, but it can also serve social purposes, as represented by the world-renowned documentary series “Cosmos: A Personal Voyage” (Sagan, 1980). It can share spaces with journalism, for example, in the form of scientific sections for newspapers or magazines, which fosters a scientific culture through the publication of

[9] See FameLab international initiative, organized by the British Council: https://www.britishcouncil.org/education/he-science/famelab (Accessed 29/04/2024).

informative articles about topical issues combined with more generic dissemination articles (SMC, 2022).

Public dissemination can appear on our libraries' most relevant shelves to meet society knowledge demands in the form of informal learning. It can also conquer prime-time spaces in mass media (Sanz Ezquerro, 2015), fostering incidental learning, such as the science shows presented in *El Hormiguero* (Catela, 2024), or the scientific late-night show *Órbita Laika* (Polo, 2023). It also spreads through radio with dedicated national programs such as *Serendipias* (SER, 2022) and through every single social media platform through the voice of scientific influencers (Meneses, 2024). Moreover, public dissemination can also fulfill the institutional goals of the research centers and universities, allowing their research to gain public visibility (Sánchez Fundora & Roque García, 2011). It is also considered by some as a social duty (García Molina, 2021). Last, public dissemination has gained popularity as a valuable complementary resource to enrich formal education (Escobar Ortiz & Rincón Álvarez, 2018; Glock Maceno et al., 2023). It can also work as a complementary tool to foster curiosity about certain knowledge domains, which the audience might further explore through formal, non-formal, and informal education (Buitrago & Torres Ortiz, 2022a).

Therefore, it is by far the most "elastic" mechanism for knowledge communication, as it spreads through platforms of highly diverse nature. It is also remarkably versatile in terms of purpose and scope and can act in a complementary way with education, journalism, and academic dissemination. This might be due to the lack of a wide own space, as it happens for education, with educational centers; for academic dissemination, with universities and research centers; and for journalism, with mass media (television, newspapers, or radio). Through decades, dissemination has tried to find its way into those spaces, adapting to their characteristics and developing synergies with the communication mechanisms owning such spaces. With the irruption of social media, there is a neutral space where public dissemination can fully develop.

Thus, modern dissemination acts in a wide range of spaces, spreading not only in its own channels and formats but also coexisting with other mechanisms for knowledge communication. For this to be successful, it is crucial to always define a clear target audience for each dissemination activity or product, which is key to defining its scope and characteristics. This implies that finding an adequate, universally valid definition of what public dissemination is and what it aims for is not trivial. Consequently, the following section will address this issue, aiming to open a space for reflections that will further define the concept of public dissemination to which this thesis refers to, as well as its boundaries and relations with other mechanisms for knowledge communication.

Interconnections between the mechanisms for knowledge communication

In the subsections above, each one of the mechanisms for knowledge communication has been introduced. There is now common ground to understand each of the Conjoined Ellipses of Knowledge Communication (see Figure 2): academic dissemination, from academics to academics; education, from educators to students; journalism, from journalists to society; and public dissemination, from disseminators to society. However, what about their interconnections?

However, as previously represented in Figure 2, there are several overlaps referring to the common areas where more than one communication mechanism can operate. Figure 3 is complementarily highlighting these overlaps, which represent the synergies between the four main ellipses: the spaces where a single activity or resource can address a dual intention towards more than one mechanism for knowledge communication.

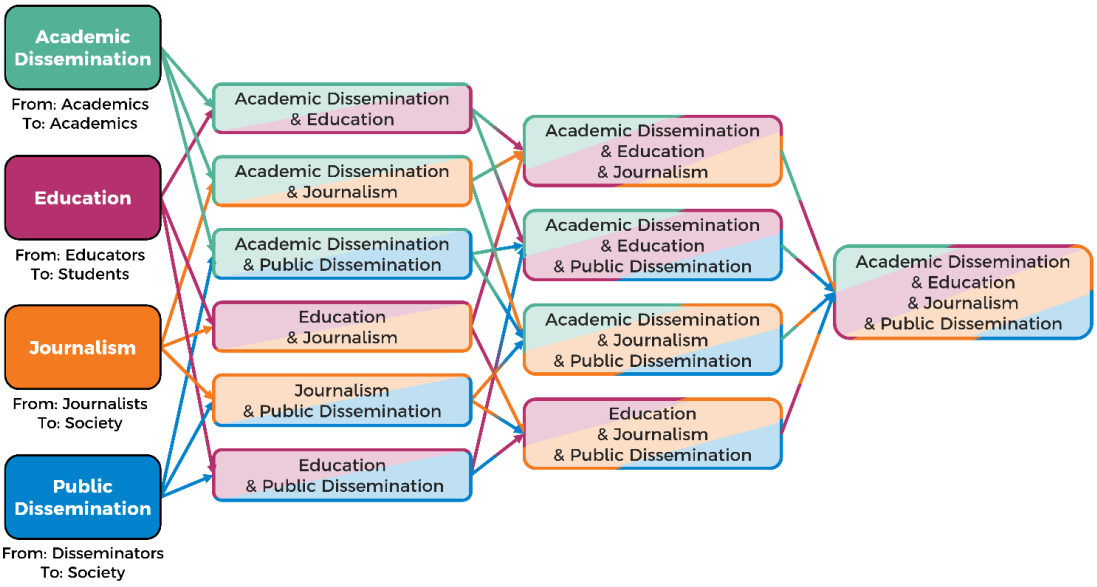


Figure 3. Schematic view of the interconnections between the mechanisms for knowledge communication.

There can be an extensive number of examples, all of them representing the versatility of the communicative environment. For instance, academic dissemination and journalism meet in initiatives such as The Conversation[10] platform. It publishes news and informative content exclusively written by academics and researchers aiming to reach society with an informative

[10] https://theconversation.com (Accessed 04/05/2024).

summary of their research. Another example of these interconnections between academic dissemination and education would be the conferences organized for young researchers, who are allowed to explore the world of academic dissemination during their studies. Academic dissemination and public dissemination also meet in initiatives such as the "Three Minutes Thesis"[11] contests, which started as a trend some years ago in universities worldwide. Similarly to the other cases, there is a clear interconnection between journalism and public dissemination when considering the science section of newspapers, TV, or radio science programs, etc.

With the same reasoning, more than two communication mechanisms might serve as an operating area for other types of formats. Ultimately, certain activities or resources might also fill the gap left at the center of the Conjoined Ellipses of Knowledge Communication. However, the more applications a resource meets, the more likely it is to become too generic and not excel, as it does not address a well-defined target audience.

Considering all the aspects presented in this section, the following sections will further explore the communication mechanisms object of study in this doctoral thesis. Therefore, the next section will elaborate on the specific role and boundaries of public dissemination, with the participation of several professionals of science dissemination from different perspectives and with various aims. It will be followed by a final section about the interconnections of public dissemination and education as a framework working area for this doctoral thesis.

0.2 The role and boundaries of public dissemination

Intending to provide a broad definition, public dissemination can be considered as the set of activities and actions of analyzing, explaining, and popularizing knowledge, culture, and critical thinking. And, though this definition partially overlaps with journalism and education, there is a main differential factor: while journalism mainly intends to inform about topical issues and education intends to provide specific academic knowledge and skills, public dissemination normally aims to generate and satisfy curiosity in the form of informal learning. Moreover, this activity should be carried out attractively and entertainingly, adapted to the target audience's knowledge

[11] https://threeminutethesis.uq.edu.au

(Calvo-Hernando, 2002). This is aimed at fostering the active engagement process in the audience, which is a critical element of the learning process (see Figure 1). However, this might be a limiting factor in the depth of the explanations.

Public dissemination of knowledge, therefore, has its own operating area. The intentional partial overlapping of the previous description with education and journalism considers the fact that public dissemination can operate in coexistence with either (as exposed in the section 0.1). In this doctoral thesis, therefore, public dissemination (which will be frequently abbreviated as just dissemination) will address such a succinct definition[12].

On the one hand, it will act as a hypernym of other frequently used terms such as social communication of science, science outreach, or public awareness of science. In this case, understanding the concept of science as a broad term is not restricted to a specific knowledge domain but to a more comprehensive range of disciplines: empirical sciences, applied sciences and technology, social sciences, humanities, etc.

On the other hand, it will leave the concept of science communication as a broader idea covering all forms of communication previously presented: academic dissemination, education, journalism, and public dissemination. The report "Science and the Public: A Review of Science Communication and Public Attitudes to Science in Britain" (Office of Science and Technology & Wellcome Trust, 2000), defines science communication as a term covering all the abovementioned mechanisms for knowledge communication, encompassing communication between: Groups within the scientific community, including those in academia and industry; the scientific community and the media; the scientific community and the public; the scientific community and the Government, or others in positions of power and authority; the scientific community and the Government, or others who influence policy; industry and the public; the media (including museums and science centers) and the public; and the Government and the public.

Entertainment and social purposes

Public dissemination is by far the broadest mechanism for knowledge communication. It can host a multiple variety of formats, aims and communicative voices. Moreover, it also spreads through entertainment and

[12] The equivalent term in Spanish would be *divulgación*, or *divulgación científica*. It will act as hypernym of *comunicación social de la ciencia, comunicación pública de la ciencia, popularización científica, vulgarización científica,* or *difusión científica*.

social purposes. This implies that a global definition of public dissemination and its boundaries might also benefit from the multiple nuances that can be provided by its different approaches.

With this aim, five renowned Spanish science disseminators have been interviewed for this section: Javier Santaolalla, Maite Iriondo de Hond, Ignacio Crespo, Laura Toribio San Cipriano, and Santiago Campillo. This collaborative discussion aims to present a common perspective about the role of public dissemination and its boundaries. First, intending to understand their individual approach toward science dissemination, they were asked about the mission of their communication activity:

- **Javier Santaolalla**: As an influencer with an academic background and a strong vocation towards formal and informal education[13], his activity mainly focuses on public dissemination and its intersection with education. "I try to contribute to people's lives. It is not only a matter of education or knowledge, but also the possibility of bringing positive feelings such as joy, wellness, or hope".

- **Maite Iriondo de Hond**: As a Scientific and Technological Evidence officer at *Oficina C*[14], also with an academic background, Iriondo considers that her activity is spread over academic dissemination and public dissemination. "In *Oficina C*, our mission is to provide the Congress of Deputies with scientific evidence on topics of interest and to facilitate the dialogue between the scientific community and the deputies. We aim to contribute to informed decision-making so that scientific knowledge is considered another dimension of parliamentary work".

- **Ignacio Crespo**: As a dissemination professional tightly involved in several Spanish mass media outlets[15], he catalogs his activity mainly in public dissemination and its intersection with journalism. "I want to evidence that science is also part of our culture, and it is interesting

[13] Dr. Javier Santaolalla: Physics PhD and MSc, and Telecommunications Engineer. Science Disseminator. Content creator in TikTok, Instagram and YouTube, with more than 10 million followers in total. Cofounder of *Amautas*, *Big Van Ciencia* and *Scenio*.

[14] Dr. Maite Iriondo de Hond: Food Science PhD, Bioinformatics MSc, and Agriculture Engineer. Scientific and Technological Evidence Officer at the Spanish Science and Technology Office of the Congress of Deputies (*Oficina C*).

[15] Ignacio Crespo: Cognitive Neuroscience specialist and Medical Doctor. Science Disseminator. Director of the Science Section at *La Razón*, and host of the national radio program *Serendipias* at *Cadena SER*.

when we can overcome the barriers imposed by its terminology and intrinsic complexity".

- **Laura Toribio San Cipriano**: As an active researcher[16], she mainly places her activity in academic dissemination and public dissemination, with a complementary tendency towards education. "I intend to tackle two parallel missions. The first one focuses on young people, bringing them closer to science so they can consider it a future career. The second one is to foster science for everyone; I try for people not to feel that the scientific world does not belong to them, that it is far away from their reality".

- **Santiago Campillo**: As a dissemination professional[17], Campillo considers that his activity is mainly covered in the public dissemination area, with a clear tendency towards journalism. "Professionally, most of my work is informative, tending to journalism. However, when disseminating through my channels, I aim to offer informative tools to society for them to make contrasted and realistic decisions on different topics". Such activity mainly focuses on a meta-dissemination approach, presenting an analysis of trends and tools for science dissemination and communication.

Democratizing knowledge

When asked about the role of public dissemination, all interviewees agreed on its importance in building bridges between science and society. "It is a way to bring scientific knowledge closer to society", says Javier Santaolalla. However, this concept is not restricted to science as a field of knowledge. In this regard, both Iriondo and Toribio highlight that dissemination is a tool that allows the democratization of knowledge (of any discipline), making it accessible to the general public. However, the science disseminator should carefully consider the veracity of the messages included in the dissemination activity or product. The

[16] Dr. Laura Toribio San Cipriano: Astrophysics PhD and MSc, and Mathematician. Researcher at the Cosmology Group at CIEMAT (*Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas*).

[17] Santiago Campillo: Molecular Biology and Biotechnology MSc, and Biologist. Science Disseminator. Science Communication advisor. Cofounder of *Vector Divulgación*, *Scenio* and *Hablando de Ciencia*.

real challenge relies on simplifying the explanations and making them more engaging while maintaining rigor to an optimal extent (see the following subsection).

In this sense, Crespo emphasizes that "the scientific knowledge is part of the culture of our civilization", considering dissemination as a tool for an accessible culture for people without the education needed to access such knowledge directly. He continues: "Instead of giving people scores of baroque music, there are chamber orchestras that play it and make it interpretable and enjoyable for people without a music background. This is also the case for public dissemination, which interprets and transmits knowledge engagingly". Public dissemination includes, therefore, the process of transforming information to adapted messages that can reach a wider target audience. Campillo remarks that "this process involves changes in format, channel, voice, formal register, style, and even content or message (always maintaining the core of the information)".

Today, more than ever, scientists are aware of the relevance of fostering knowledge transfer to society. "Results cannot stay in the laboratory", states Iriondo. "But not all of us can actively engage in dissemination activities, since workloads are usually very high, and this additional task requires preparation and time". Dissemination professionals are needed to contribute to the democratization of knowledge with rigor and proper dedication. However, dissemination is not only about telling the latest science news anecdotally, which may be more related to the aims of scientific journalism. Toribio adds that "it is also about digging to the roots to explain how knowledge is born and how we advance in the different knowledge domains". Fostering critical and scientific thinking is, therefore, a fundamental part of the intention of public dissemination.

Disseminating with veracity and optimal rigor

The advent of social media has made it easier for scientific knowledge to be shared in a format that is more accessible and enjoyable for society (Cárdenas, 2017). It has significantly transformed the communication landscape, democratizing not only the access to knowledge (from the audience's perspective) but also the dissemination of knowledge (from the disseminators' perspective).

This shift has been largely positive, as it empowers individuals to share information and ideas with the general public, breaking down the barriers that once limited the spread of knowledge to a select few through traditional mass

media. However, this democratization also comes with its own set of challenges. In this regard, Iriondo expressed that "dissemination in social media in many cases replaces the search in other traditional media such as press, television, or radio. This brings with it a great challenge for the consumer: to be able to differentiate between evidence-based information among so much misinformation." It is not only a matter of the quantity of information spread through social media but also of the fact that social media have no regulatory organizations reviewing and overseeing the disseminated content.

The ease of access and the ability to share content widely, together with the lack of such regulatory organizations, has led to increased media noise, with a plethora of relevant and irrelevant information. More critically, it has heightened the risk of misinformation (Quesada Cubo & Navarro Ardoy, 2023). Fals information can be propagated rapidly without peer reviews, checks, and balances, leading to confusion and potentially harmful consequences. This situation has generated many prejudices from the academic community concerning public dissemination, particularly regarding the parameters of veracity, rigor, and content quality (Buitrago & Torres Ortiz, 2022b; Vizcaíno-Verdú et al., 2020). These prejudices are mainly based on the lack of review mechanisms to guarantee that the information spread online is accurate enough, together with the simplifications needed to achieve the public dissemination purpose appropriately.

However, it is essential to differentiate between the intrinsic needs of rigor in academic dissemination, and the communication needs of public dissemination. According to Campillo, "rigor, by definition, is related to precision, or property. In the scientific world, where reproducibility is a necessity, veracity, and quality are identified with rigor because precision allows the validation of a hypothesis adequately. However, an excess of precision, in a completely different environment, such as the communicative one, can be detrimental to the objective of the communication itself". It is the metonymy between rigor and veracity. Public dissemination must guarantee the veracity of the information and messages, but the precision (rigor) would be a relative parameter adapted to the target audience.

Despite these prejudices, it is undeniable that dissemination resources exist, and they are both demanded and widely used. Not in vain, Gil-Quintana et al. (2020) documented how edutubers (educational content creators on YouTube) might be perceived as a preferred academic reference for students. This is due to some of the characteristics of the communicative model used by disseminators and edutubers, and their high engagement rates and interaction with the audience. It is true that the free circulation of ideas online opens a room for pseudoscience content and manipulation. Still, the challenge of public dissemination is to deal with this scenario also to provide interesting,

engaging, and truthful information. In this line, dissemination materials might also be invaluable as didactic resources.

The challenge, then, seems to be related to being able to differentiate truthful information from misinformation[18] and disinformation[19]. Research suggests that fake news spreads farther, faster, deeper, and more broadly than the truth (Vosoughi et al., 2018). Therefore, society faces the challenge of finding a balance between upgrading critical thinking skills and the growing quantity of fake news and information, and the increasing speed at which it spreads. This is not only a problem for truthful and rigorous public dissemination but also for any other form of knowledge communication.

Therefore, even though disseminators have the moral duty of communicating truthful content, the responsibility of appropriately selecting rigorous and truthful dissemination content also lies in the audience. As per Iriondo's view, "It is necessary to educate in critical thinking so that people can distinguish truthful information from untruthful information". In addition to the development of these skills through formal education, proper scientific dissemination also contributes to developing critical thinking abilities (Eagleman, 2013; Vázquez-Alonso & Manassero-Mas, 2018). Sharing the knowledge generated through research and the methodology leading to such results is crucial. It is not only a matter of sharing knowledge but also fostering scientific and critical thinking. "Otherwise, pseudoscience and other fake information will occupy a wider space in the communicative landscape, and it can be dangerous", states Laura Toribio.

It is often presumed that the communicating party possesses advanced knowledge of the specific topic being disseminated, which is to be transferred to the general public (Kohler & Dietrich, 2021). However, this is not always true, and it seems to be crucial that users know how to select appropriate videos and also critically judge the content quality and source of information (Kohler & Dietrich, 2021; Kulgemeyer, 2018). In this line, research efforts are being directed at establishing adequate metrics and rubrics to evaluate the quality of dissemination resources (see the subsection 1.2.5).

The modern landscape of dissemination

Traditional scientific dissemination was mainly through television, radio, newspapers, magazines, books, and conferences. Now, modern dissemination

[18] Misinformation: false or inaccurate information; understanding the facts wrong (APA, 2024).
[19] Disinformation: false information which is deliberately intended to mislead; intentionally misstating the facts (APA, 2024).

has been shaped by the popularization of social media, which fosters a democratization of dissemination and conditions the public's relation to its referents. Instead, there is a richer landscape of dissemination referents.

The irruption of Information and Communication Technologies (ICT), together with social media, has revolutionized the landscape of scientific information from the perspective of both the audience and the creator. It would be impossible to fully understand the current reach and trends of public dissemination without considering these new communication technologies. Moreover, the COVID-19 pandemic significantly increased the presence of STEM content both in mass media and social media (Quesada Cubo & Navarro Ardoy, 2023). Additionally, according to the latest report evaluating the social perception of science and technology in Spain (FECYT, 2023), the social interest in scientific and technical topics is similar to that of topics such as politics, education, environment and ecology, or inflation.

Regarding traditional media, on the one hand, Crespo mentions that "the pandemic made them see an opportunity towards science communication in a very utilitarian way, because the main objective is to gain visits". In his view, mass media increased the presence of science content in a form of clickbait "generating concern by giving rise to issues such as asteroid threats, solar storms and other apocalypses". However, this has allowed to demonstrate that there was an underlying social interest towards science, something that Crespo sees as an opportunity: "it has allowed, over the last few years, that more people could professionalize their scientific dissemination activity than ever before".

On the other hand, social media have also become a central tool for public dissemination. Iriondo views them as "tools that make it easy to upload material for dissemination, as well as to consume it. In addition, the reach of information on social media is global". Santaolalla adds that "the creation and consumption of dissemination material has become massive. There has been a renewal in terms of the ways of communicating, as well as a proliferation of disseminator profiles".

This situation indicates that we might be living in a period of historical maximum interest and exposure of science to the general public in Spain. "We have never seen so much dissemination, so many disseminators, so much product and so much interest as nowadays", highlights Campillo. "Dissemination offers a surprising amount of information to a staggering number of people, who can access it in a way that is almost personalized to their tastes and needs. This starkly contrasts how restricted its scope was just two decades ago".

However, despite the exposure of dissemination contents and the growth of interest, it seems that the referents in this field are of a different nature than

those two decades ago. The modern dissemination landscape is no longer composed of a few rock-star-alike disseminators such as Carl Sagan, Jane Goodall, or Félix Rodríguez de la Fuente. Instead, there are uncountable referents considering different niche fields and geographical areas. The fact that there are more communication channels, together with the democratization of content creation, allows for niche content but also further divides the interest of the public. "This implies that there is not a phenomenon as resounding as what happened decades ago, when we watched a guy or girl on TV talking about science because it was the only channel we had. And then, by chance, we discovered that they were awesome!", Crespo said. "It is not that they were from another planet. This phenomenon is determined by the context in which they existed".

This democratization of content creation enriches the dissemination landscape, adding several voices, perspectives, and experiences to the discourse. One of these perspectives is that of academics who, from a vocational perspective, dedicate part of their time to sharing their knowledge. "When I started to disseminate science, more than ten years ago, it was frowned upon for a scientist to devote her time to such activity", Toribio explains. "My task was expected to be research, and the transmission of knowledge to the public was considered a waste of time". Fortunately, this situation has changed completely. "Today, that view has changed for the better. It is now understood that among the activities carried out by scientists, it is also important to disseminate knowledge". And this is good news for us all. Thus, we can count on referents from the academic world to bring us first-hand stories from the factory of knowledge.

Social media runs fast. More information is being shared than ever, and the more volatile a content is, the more volatile the referents are. However, it is not a matter of fame but instead of information availability. We no longer have a single bright star on a black night. Instead, we can now enjoy starry nights with hundreds of glittering dots. Isn't that a landscape worth enjoying?

0.3 Potential interconnections between dissemination and education

After drawing a common sketch representing the concept of public dissemination, its scope, and its purpose, let's resort to the Conjoint Circles of Knowledge Communication represented in Figure 2. This section will focus on

the interconnection between public dissemination and education, as a framework for this doctoral thesis. Are dissemination resources adequate to be used in formal education? What would their role be in such a context? Are they only relegated to spark curiosity in a specific topic, or can they be used as a complementary conceptual or procedural learning tool?

"We should differentiate between dissemination and education, which, by definition, are deontologically different and have different scopes of application", Campillo expresses. "This means that both education and dissemination are needed, without forgetting one or the other. However, due to its characteristics, dissemination is the perfect companion to education. It allows to complement the presentation, expansion or consolidation of the knowledge distributed in education". Toribio adds that "there are dissemination resources that can be useful for education. For example, a 10-minute video can generally show students what they will learn in class, as well as some curiosities that teachers can later expand. Another example could be dissemination books, for those students who want to further explore content not covered in the scope of the school curriculum."

Due to its scope and action area, dissemination explores formats, messages, approaches, and a communicative voice that would be improbable in formal education. In that sense, Crespo points out that "possibly, the science disseminator has time and focus to develop their contents in a way that for teachers would be impossible inside the classroom. Therefore, disseminators will probably develop their content with greater originality, offering a different perspective that can streamline the teachers' work, and providing a different approach".

These ideas are reflected in Santaolalla's experience: "I am actually aware that many of my videos are used in classes by both students and teachers", he mentions, discussing the importance of dissemination resources in showing students' alternative ways to explain and conceive abstract and complex topics. And this is not restricted to the audiovisual format. In this sense, Iriondo comments that "some of the reports that we develop at *Oficina C* are being used in universities as reference material for certain courses". However, she also adds the nuance that they might not be appropriate for other educational stages. "It is necessary to adapt the resources to each educational stage and consider the needs of each audience". Santaolalla adds that "the science disseminator transmits knowledge to society, and the teacher should make that extra effort to take the dissemination activity, adapt it to the classroom, and delve into it. This combination allows them to present the contents in a dynamic, interesting, and attractive way, in the context of their teaching needs".

Considering such a joint effort, education can extensively benefit from public dissemination resources. In this tandem, on the one hand, the science disseminator would focus on the development of useful, original, and engaging resources. These can satisfy the aims of public dissemination while having a potential side value for formal education. On the other hand, teachers and professors need to take a step forward and integrate such resources (those that are suitable) into their instructional design.

However, these synergies might be simplified if each party considers this common area as fertile ground that might benefit both. This is where this doctoral thesis is framed. From the perspective of the science disseminator, they could specifically cover topics of relevance for different disciplines aligned with the curriculum. This way, the resulting dissemination resources could be easily linked to various parts of the syllabus, favoring its fit as a resource to contribute presenting, expanding, or consolidating the course contents. From the perspective of educators, they should also work on enhancing their digital competences to properly integrate digital resources into their class dynamics. Moreover, enhancing their pedagogical competences will contribute to creating proper instructional designs that successfully incorporate dissemination resources when relevant.

Depending on the specific needs of both the course's contents and the developed instructional designs, different formats of dissemination resources might be more suitable. As previously mentioned in the sections 0.1 and 0.2, there is a wide range of dissemination formats where to choose from, among which we can find books, articles (either in newspapers, magazines, or blogs), talks and monologues, videos, podcasts, comics, etc. There are as many formats as the imagination can reach.

All of them can provide specific added value depending on the teaching strategy. However, in this context dissemination videos have become a particularly relevant format for education. They communicate their content benefiting from a dual information transmission channel (visual and auditory), optimizing our processing capacity. They also offer a more engaging approach than text-based content to capture students' attention and interest. They can also be paused, rewound and rewatched, allowing students to learn at their own pace. They are also a valuable tool to show processes or phenomena that would otherwise be difficult to demonstrate in a classroom setting.

This doctoral thesis intends further to explore these connections between public dissemination and education, aiming to build bridges that can benefit both disseminators and educators. It will specifically address the potential pedagogical value of dissemination videos in education as a complementary resource. These pages will dive deep into these intricacies, further exploring

the implications of designing dissemination videos optimized for use in formal education.

Organization of the doctoral thesis

The first chapter of this doctoral thesis introduces the topic and provides a literature review, focusing on the potential pedagogical value of dissemination resources. This sets the stage for identifying the research gaps and drafting the frontiers of current knowledge on the educational use of STEM dissemination videos. The next chapter outlines the research strategy, detailing the objectives and methodology of the study. It is followed by a contributions chapter, where the developed research builds upon the identified research gaps.

The core of this doctoral thesis is a compendium of three journal articles. The first article assesses the users' perception of the current and potential value of a STEM dissemination YouTube channel. The second article explores the impact of electrical engineering didactic videos during Emergency Remote Learning (ERL) scenarios. The third article presents a six-year data analysis comparing educational and dissemination videos on a STEM YouTube channel.

Finally, the doctoral thesis presents a final chapter with conclusions and future works, discussing the bidirectional path of education and dissemination.

INTRODUCTION AND LITERATURE

THE POTENTIAL PEDAGOGICAL VALUE OF STEM DISSEMINATION

1. Introduction and Literature: The potential pedagogical value of STEM dissemination

In the dynamic landscape of education, the interplay between knowledge dissemination and effective pedagogy might be a beneficial nexus. This first section of the doctoral thesis introduces the multifaceted relationship between education and dissemination within the context of Science, Technology, Engineering, and Mathematics (STEM) education.

First, the relevant framework of this doctoral thesis will be introduced, resorting to the leading educational theories and methodologies that are fundamental for STEM education and video integration as a didactic resource. Then, the current relevant literature on video-based learning in STEM disciplines will be presented, aiming to provide a big picture of the status of research about the impact of videos in formal education and the role of YouTube and STEM dissemination content creators in this context. In an era dominated by digital media, video content has become a powerful tool for STEM dissemination and education. But how do well-crafted videos engage learners? What cognitive processes are triggered when students encounter visual explanations? This section will examine the empirical evidence and the theoretical underpinnings to unravel what we know so far about the impact of video content on STEM education. Finally, the last subsection will summarize the current research gap, which this doctoral thesis intends to address. This analysis has defined this research line objectives and questions, intended to bridge the gap between STEM dissemination and education.

1.1 Relevant Framework

This section aims to study the theoretical framework that guides our understanding and applications of pedagogical and didactic strategies in the digital era. The framework selected covers the three main factors involved in video selection for educational purposes, as shown in Figure 4.

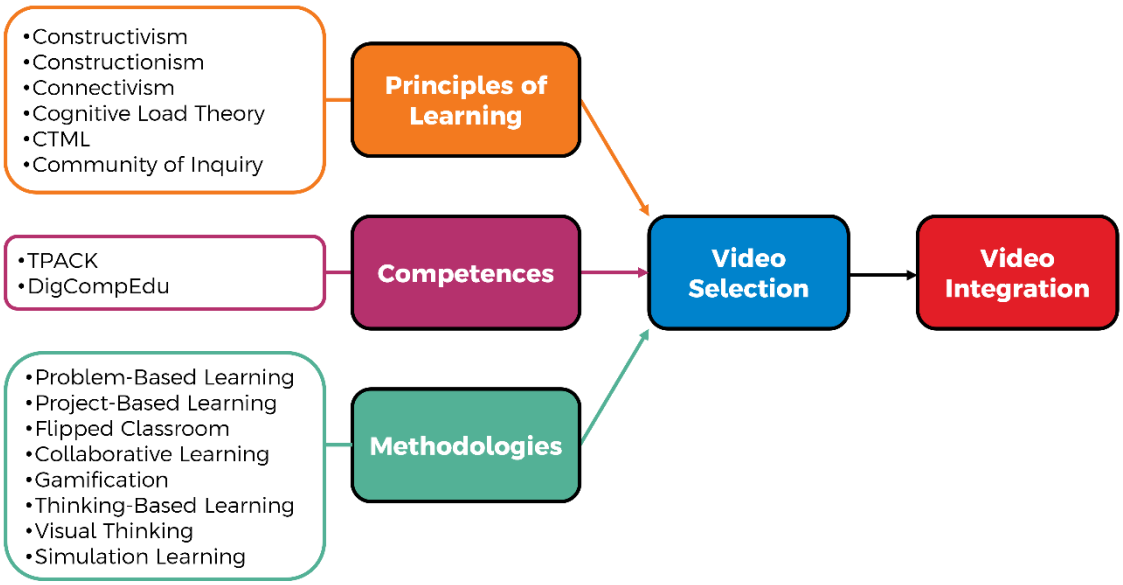


Figure 4. Concept map of the relevant framework for this doctoral thesis.

Therefore, this section starts by exploring the principles of learning through constructivism, constructionism, and connectivism, which emphasize the active role of learners in constructing their knowledge, and the importance of networks in such a learning process. Then, the Cognitive Load Theory (CLT) and the Cognitive Theory of Multimedia Learning (CTML) are analyzed to provide insight into how information processing can be optimized through videos as a didactic resource for effective learning. The Community of Inquiry (CoI) framework is also reviewed for its emphasis on social, cognitive, and teaching presence in online learning environments, and how the interaction between pairs can benefit social media involvement in instructional design.

Then, two relevant frameworks on teaching competences are presented. The Technological Pedagogical Content Knowledge (TPACK) framework is discussed first, highlighting the intersection of technology, pedagogy, and content in education. Second, the European Framework for the Digital Competence of Educators (DigCompEdu) is presented, emphasizing the need for academics to develop adequate digital competences. Finally, Active Learning Methodologies are discussed, which engage students through their learning process. Special

attention will be paid to those methodologies to which videos might be used as a vehicular resource, such as the flipped classroom, the visual thinking methodology, or collaborative learning.

Each of these frameworks offers valuable perspectives for designing and implementing effective technology-enhanced learning experiences and are, therefore, relevant to this doctoral thesis.

1.1.1 Constructivism, Constructionism and Connectivism

In this section, the intricate realms of Constructivism, Constructionism and Connectivism are explored. These three pivotal theories have significantly shaped our understanding of knowledge acquisition and learning. Together, these theories provide a comprehensive framework for exploring the multifaceted nature of learning.

Constructivism

As a learning theory, constructivism buries its roots in the late 19th century, when the idea of student-centered education was being explored. Some of the main early proponents of constructivism included Jean Piaget, Lev Vygotsky, and John Dewey, although the theory is traced back to educational psychology in the theory of cognitive development (Piaget, 1971). In this theory, Piaget focused on how humans create meaning by interacting with their experiences and ideas.

The educational theory of constructivism postulates that learners are not merely passive recipients of knowledge through a direct, unidirectional process of knowledge transmission. On the contrary, learners actively construct novel understandings and knowledge by synthesizing new information encountered through experiential learning and social discourse and integrating it with their pre-existing knowledge base (Bada & Olusegun, 2015). This process of knowledge construction is, therefore, a dynamic integration of the new information with prior knowledge. It also suggests that learning is influenced by the context in which an idea is taught and the learners' beliefs and attitudes (Zajda, 2021).

The fundamental ideas of constructivism are:

- **Construction of knowledge:** The cornerstone of constructivism is that knowledge is not simply received, but rather constructed from integrating new information within pre-existing knowledge.
- **Active learning process:** Constructivism posits that learning is an active process wherein learners continually interact with their peers or instructors through participatory methods such as discussions.
- **Incremental learning:** According to constructivism, individuals learn as they acquire knowledge. Each concept a person comprehends paves the way for a deeper understanding of future concepts and ideas.

From the perspective of constructivism, educational technologies are potential tools for enacting curriculum through specific pedagogic approaches (Makewa et al., 2019; Taber, 2017). In the context of technology, constructivist learning can be facilitated by various digital tools that allow learners to interact, manipulate, and experiment with objects of study. As an example, virtual simulations can provide a dynamic and interactive environment for learners to explore and construct knowledge. New technologies, therefore, include alternative ways to bring about learning within an established strategy, for which educators must develop adequate digital and technological competences.

However, constructivism is also subject to criticism mainly due to its similarities with discovery learning, and to the consideration that it is attempting to overanalyze what some consider to be a triviality (Osborne, 2014). Moreover, some critics also argue that constructivism does not provide how to develop an effective pedagogy, lacking clear guidelines or strategies for teaching (Babakr et al., 2019; Osborne, 2014). Notwithstanding, it is worth noting that, while these criticisms exist, many educators and researchers continue to find value in constructivist approaches to learning and teaching as building blocks for the educational practice and the development of further theories in the field of education (Kara, 2018; Prakash Chand, 2023; Theelen & Van Breukelen, 2022; Yakar et al., 2020).

Constructionism

Constructionism is often confused with constructivism because of their interlinked nature. However, while constructivism emphasizes that individuals construct knowledge through mental processes, such as assimilation, accommodation, and reflection, constructionism focuses on learning by creating or constructing something. It posits that individuals learn best when they actively engage in hands-on activities that involve the creation of tangible

objects or projects (Rob & Rob, 2018). Elaborating on this idea, constructionism is a learning theory suggesting that individuals build their comprehension and knowledge of the world by experiencing things and reflecting on those experiences (Kafai, 2005). It emphasizes the importance of the process in which the learning is engaged in constructing something meaningful. Hence, it's a pedagogy focused on students, promoting the construction of their knowledge through an active learning process.

The theory was developed by Seymour Papert, extending the constructivist theories of Jean Piaget to emphasize the role that technology and active, hands-on activities can play in the learning process. This conceptualization of learning is fundamental in today's understanding of STEM education, considering that computers provide a suitable platform for students to construct and experience their ideas, as well as the introduction and application of computational thinking as a cognitive ability. Moreover, computational thinking started being formally and extensively introduced in Europe during the decade 2010 (Bocconi et al., 2022), and it was integrated into the educational curriculums in Spain in 2023 with the LOMLOE educational regulation (Ley Orgánica 3/2020 de 29 de Diciembre, Por La Que Se Modifica La Ley Orgánica 2/2006, de 3 de Mayo, de Educación, 2020; Real Decreto 95/2022, de 1 de Febrero, Por El Que Se Establece La Ordenación y Las Enseñanzas Mínimas de La Educación Infantil, 2022; Real Decreto 157/2022, de 1 de Marzo, Por El Que Se Establecen La Ordenación y Las Enseñanzas Mínimas de La Educación Primaria, 2022; Real Decreto 217/2022, de 29 de Marzo, Por El Que Se Establece La Ordenación y Las Enseñanzas Mínimas de La Educación Secundaria Obligatoria, 2022).

Therefore, computational thinking is nowadays a core competence in STEM education because it enhances problem-solving skills and advanced analytical abilities. Moreover, it is a multidisciplinary concept that goes beyond programming and computer science and can apply to all STEM fields. These skills were developed under Papert's didactic proposal through his Logo programming language for education, particularly aimed at developing logical and mathematical thinking from an early age (Papert, 1991, 2000).

Constructionism extends constructivism by underscoring the significance of learners creating tangible artifacts in the real world. The advent of technology implies that this can include digital artifacts such as programs and codes, and other digital objects such as video files. For instance, students might use coding platforms to create their own programs or digital art, and open-source software to create their didactic videos. This hands-on approach allows learners to make meaningful connections between their creations and the concepts they are learning (Byrne et al., 2021).

Connectivism

Connectivism is a learning theory for the digital age. It explains how internet technologies have created new opportunities for people to learn and share information across the World Wide Web and among themselves. This theoretical framework focuses on digital technologies such as web browsers, search engines, wikis, online discussion forums, and social networks, and how they contribute to new avenues of learning. It emphasizes the role of the social and cultural context in the process of learning (Glassner & Back, 2020; Sagar, 2014).

George Siemens initially proposed this theory in 2004, and Stephen Downes later elaborated on it. It emerged as an innovative learning model adapted to the networked world we live in, proposing that learning and knowledge rest in a diversity of opinions and that learning is a process of connecting specialized nodes or information sources.

According to Siemens (2005), the core principles of connectivism include:

- **Diversity of opinions:** Learning and knowledge rest in the diversity of opinions. Connectivism values the unique perspectives and experiences that each learner brings, recognizing that everyone's unique experiences and viewpoints contribute to a richer, more comprehensive understanding of a subject.
- **Learning beyond humans:** Learning may reside in non-human appliances, reflecting the digital age where machines and software can also learn and adapt. It acknowledges the role of artificial intelligence and machine learning in the modern learning landscape.
- **Learning over knowing:** It emphasizes the process of learning over the state of knowing. It values learning and adapting to new information over static knowledge. This principle underscores the importance of lifelong learning in an ever-changing world.
- **Connecting information sources:** Learning is a process of connecting specialized nodes of information sources. These nodes could be people, databases, or other resources. The connections between these nodes create a network of knowledge that facilitates the flow and exchange of information.
- **Seeing connections:** Connectivism considers as a core skill the ability to see connections between fields, ideas, and concepts. It values multidisciplinary learning and the ability to integrate knowledge from different domains. This principle encourages learners to draw connections across various disciplines, fostering a holistic understanding of the world.

- **Maintaining connections:** Connectivism also underscores the importance of nurturing and maintaining connections for continuous learning. These connections could be social, conceptual, or neural. This principle highlights the importance of relationships and networks in the learning process.
- **Up-to-date knowledge:** This principle asserts that learning activities intend to maintain up-to-date knowledge, recognizing that in our rapidly changing world, knowledge mist be continually updated to remain relevant. It emphasizes the importance of staying current with the latest developments and trends in our fields of study.
- **Decision-making as learning:** In connectivism, decision-making is a learning process itself, suggesting that choosing what to learn and interpreting incoming information is seen through a shifting reality. This principle acknowledges that while there may be a correct answer now on a particular topic, it may be incorrect in the future due to the rapid changes in the information environment. This principle underscores the dynamic nature of knowledge and the importance of adaptability in the learning process.

Connectivism highlights the crucial importance of digital tools in contemporary education, acknowledging that our era of connectivity provides limitless opportunities for molding our educational paths.

1.1.2 Cognitive Theories and Multimedia Learning

This section presents two pivotal theories in educational psychology that are especially relevant when it comes to the use of videos in education: the Cognitive Load Theory (CLT) and the Cognitive Theory of Multimedia Learning (CTML). Both theories, grounded in our understanding of human cognitive architecture, offer valuable insights into optimizing instructional strategies and multimedia design to facilitate effective learning. This exploration will provide a basic understanding of these theories and their implications for educational practice.

CLT: Cognitive Load Theory

John Sweller developed the CLT in the late 1980s after a study in problem-solving (Sweller, 1988). It posits that effective instructional design can reduce cognitive load in learners, thereby enhancing learning outcomes. This model

explains how, in the learning process of individuals, there are three types of cognitive load involved: intrinsic, extraneous, and germane (Chandler & Sweller, 1991; Sweller, 1999, 2011). These cognitive loads offer a helpful framework for instructional design, as they help to identify what parameters might cause difficulties in the teaching-learning process.

- **Intrinsic (or essential) cognitive load:** It is associated with the complexity of the topics. Therefore, it is defined by the inherent difficulty of the concepts to be learned and, consequently, it is a pre-defined challenge. However, the intrinsic cognitive load increases in knowledge areas containing a high presence of abstract concepts, such as the STEM disciplines.
- **Extraneous cognitive load:** It is associated with how the information is presented and the potential distractions. This type of cognitive load is partially under the control of the instructional designers because it is directly related to the instructional materials. However, the learning environment might also affect this type of cognitive load. An example of an unprecedented learning environment that increased the extraneous cognitive load is ERL due to the COVID-19 pandemic, as it challenged the existing teaching methodologies and forced changes without proper planning or resources. This new learning context led to additional difficulties such as concentration problems, reduced interaction, stress and anxiety towards learning, or loss of motivation and interest in the courses studied.
- **Germane cognitive load:** It refers to the processing of information. It is associated with creating links between the new information (processed by the working memory) and the previous knowledge (stored in the long-term memory). This type of cognitive load is increased when it is specifically complex to establish effective connections between the different conceptual areas that compose the studied discipline, and, therefore, it is also related to how complex and multidisciplinary the contents are.

Considering that the cognitive capacity is limited, instructional designers might consider an adequate balance of the abovementioned cognitive loads. For example, when considering particularly complex disciplines, the intrinsic and the germane cognitive loads will be high. This fact complicates the process of teaching and learning. In these cases, the instructional design must consider descriptions and materials that reduce the extraneous cognitive load, leaving enough room for the processing of the others.

CTML: Cognitive Theory of Multimedia Learning

Based on CLT, the CTML explores the impact of multimedia resources on the processing capacity of learners. This theory underscores the importance of well-designed multimedia for efficient and meaningful learning. It was initially developed by Moreno and Mayer (Moreno & Mayer, 1999), and it states how deeper learning can occur when there are two channels of information transmission (verbal and pictorial) instead of either of them separately (Mayer, 2014, 2017; Mutlu-Bayraktar et al., 2019).

Three initial assumptions constitute the foundations of the CTML. They are based on how the human mind works, as explained by research in cognitive science, and were summarized by Mayer and Moreno (2003) as follows:

- **Dual channel:** Humans possess separate information processing channels for verbal and visual material. This assumption is based on Paivio's (1990) dual-coding theory, as well as Baddeley's (1990) theory of working memory.
- **Limited capacity:** There is only a limited amount of processing capacity, which can be put in place to analyze the information received through verbal and visual channels. This assumption is central to the CLT exposed in the previous subsection (Chandler & Sweller, 1991; Sweller, 1999), and in Baddeley's (1990) theory of working memory.
- **Active processing:** Learning requires substantial cognitive processing in the verbal and visual channels. This assumption is central to Wittrock's (1989) generative learning theory, as well as Mayer's (1999, 2002) selecting-organizing-integrating theory of active learning.

Figure 5 represents a concept map for CTML, adapted from (Mayer & Moreno, 2003).

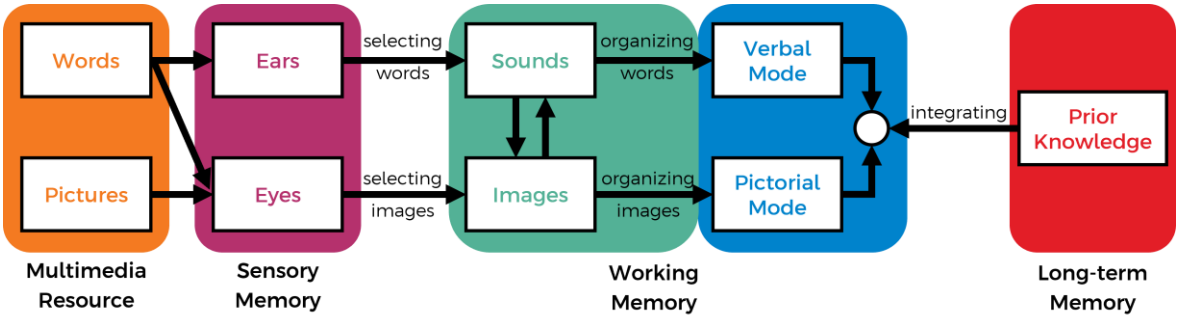


Figure 5. Concept map of the Cognitive Theory of Multimedia Learning, adapted from (Mayer & Moreno, 2003).

The two main workstreams for information processing are represented in the rows, including the auditory/verbal channel on the top and the visual/pictorial on the bottom. Moreover, the five columns illustrate the types of knowledge representations, either physical (e.g., words or pictures), sensorial (ears or eyes), shallow working memory representations (e.g., sounds or images received by the learner), deep working memory representations (e.g., verbal and pictorial models constructed by the learner), and long-term memory representations (e.g., the learner's relevant prior knowledge on the topic). The arrows represent the cognitive processing.

From these principles, Clark and Mayer (2016) further developed a series of seven principles to understand how multimedia material characteristics can be optimized for educational purposes.

They are summarized as follows:

- **Multimedia principle:** Words and pictures are better than just either alone.
- **Contiguity principle:** Words should be aligned with corresponding graphics or pictures.
- **Modality principle:** Words are better presented as audio narration than on-screen text.
- **Redundancy principle:** Visuals should be explained with words in audio or text, but not both.
- **Coherence principle:** Incorporating interesting material that might not be relevant to the explanations might make the learning process difficult.
- **Personalization principle:** The presentation style of contents should be conversational, and it is beneficial to count on virtual presenters or teachers.
- **Segmenting and Pretraining principle:** Complex topics might be divided into ordered parts to make them more understandable and foster a sequential and linked learning process. Moreover, pretraining might be relevant when complex concepts are delivered.

CTML and CLT explain the mechanisms and benefits of video integration in learning environments. These will be further introduced in the section 1.2.

1.1.3 Community of Inquiry

Early pragmatist philosopher Charles Sanders Peirce first introduced the Community of Inquiry (CoI) as a concept, which was then broadened by John Dewey with its application to the educational setting. Moreover, Matthew

Lipman was inspired by Dewey's works and continued developing CoI extensively in its application to children's education within the Philosophy of Children program (Pardales & Girod, 2006). CoI is broadly defined as any group of individuals involved in empirical or conceptual inquiry into problematic situations. It was a novel concept concerning the nature of knowledge formation and the process of scientific inquiry.

However, in the field of education, the CoI framework theory, methodology, and instruments were developed through the research project funded by the Canadian Social Sciences and Humanities Research Council, "A Study of the Characteristics and Qualities of Text-Based Computer Conferencing for Educational Purposes", which ran from 1997 to 2001 (CoI, 2017; Garrison et al., 1999)

To create an adequate CoI, Garrison (2016, 2019, 2020) describes the design principles as follows:

- **Plan for the creation of open communication and trust:** Involves creating an environment that encourages open and honest communication, which is essential to build trust among participants.
- **Plan for critical reflection and discourse:** This plan involves encouraging participants to critically reflect on their own and others' ideas, and engage in meaningful discourse.
- **Establish community and cohesion:** Involves fostering a sense of community and cohesion among participants of the CoI, which is crucial for collaborative learning.
- **Establish inquiry dynamics (purposeful inquiry):** Involves creating a dynamic of inquiry where participants are actively engaged in the learning process.
- **Sustain respect and responsibility:** Involves maintaining a respectful and responsible environment where all participants feel valued and accountable for their contributions.
- **Sustain inquiry that moves to resolution:** Involves ensuring that the inquiry process leads to the resolution of problems or the achievement of learning objectives.
- **Ensure assessment is congruent with intended processes and outcomes:** Involves aligning assessment strategies with the intended learning processes and outcomes.

These design principles incorporate issues of social, cognitive, and teaching presence and provide a roadmap for the design of effective online learning environments within the CoI framework.

When considering online learning (both in distance education situations or as a complement to traditional education), ICT allows creating virtual communities that boost learning through search and interaction among pairs. Through the creation of these communities, students are involved in social, cognitive, and lecturer's presence, which are the three primary constructs for a successful constructivist interaction as defined by the CoI paradigm (Garrison & Arbaugh, 2007; Nizzolino & Canals, 2021). CoI acknowledges this active component (online participation and practical activities in online learning environments) as vital to develop a successful and sustainable online learning experience. CoI also explains the enhancement of the educational experience by improving parameters such as content engagement, interaction with pairs through video-related activities, and self-regulated learning.

However, for the proper application of online communities to education, as well as the other mentioned principles of learning relying on educational technologies, educators should develop their technological and digital skills. Several digital tools and technological equipment are needed to create online sites and communities, together with the creation and edition of videos as a relevant format to foster and boost such communities. Only with appropriate digital competence will a successful integration of ICT in learning be achieved, with its endless possibilities and benefits.

1.1.4 Technological and Digital Competences

In the rapidly evolving digital age, the need for technological and digital competences in the field of education should not be overstated (Timotheou et al., 2023). This section will introduce the intricacies of the Technological Pedagogical Content Knowledge (TPACK) model, and the European Framework for the Digital Competence of Educators (DigCompEdu). These frameworks provide a comprehensive understanding of the interplay between technology, pedagogy, and content in an educational context, as well as the path to evaluate and enhance digital competences adequately. They are essential guides for educators to integrate digital technologies into their teaching practices effectively.

TPACK: Technological Pedagogical Content Knowledge

In the current educational setting, with the growing introduction of educational technologies, there is a specific need for educators to enhance

their technological and pedagogical knowledge, as specialization in their particular discipline might not be enough for a suitable implementation of technology-aided strategies (Auerbach & Andrews, 2018; Kim & Ahn, 2018). The Technological Pedagogical Content Knowledge (TPACK) framework has become a prominent subject teacher education studies. Its purpose is to identify the nature of knowledge educators require to incorporate technology into their teaching, addressing the intricate, multidimensional, and context-dependent aspects of teacher knowledge (Mishra & Koehler, 2006). TPACK describes the need for this continuous knowledge improvement of lecturers with a view to the successful integration of ICT in educational environments (Angeli & Valanides, 2009; Irwanto, 2021; Kadıoğlu-Akbulut et al., 2020; Mientus et al., 2022; Njiku, 2023).

The development of the TPACK framework is primarily attributed to the work of Matthew J. Koehler and Punya Mishra, building up on Lee Shulman's construct of Pedagogical Content Knowledge (PCK) to include technological knowledge (Koehler & Mishra, 2009; Mishra & Koehler, 2006; Shulman, 1987). Their work emphasizes that effective teaching with technology requires an understanding of how technology relates to pedagogy and content (Koehler et al., 2013; Rosenberg & Koehler, 2015). The fundamental principles constituting the TPACK framework are represented in Figure 6, adapted from (Koehler & Mishra, 2009).

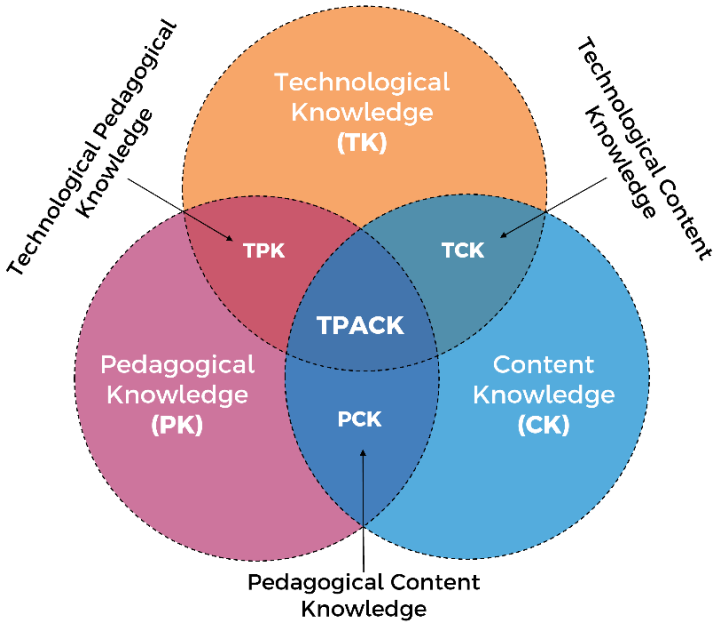


Figure 6. Venn diagram of the TPACK framework and its knowledge components, adapted from (Koehler & Mishra, 2009).

These principles are also summarized in the following knowledge components:

- **Technological Knowledge (TK):** This component refers to the understanding of diverse forms of technology, spanning from low-tech tools like chalk and blackboards to high-tech resources such as digital computers, the internet, and multimedia.
- **Pedagogical Knowledge (PK):** This component includes understanding the methodologies and procedures involved in imparting and acquiring knowledge. It encompasses familiarity with the tactics or approaches to be implemented in a learning environment, the nature of the target audience, and the methods for evaluating learners' understanding.
- **Content Knowledge (CK):** This component refers to the educator's knowledge about the subject matter to be learned or taught.
- **Technological Content Knowledge (TCK):** This component involves understanding how technology can create new representations of specific content the subject matter.
- **Technological Pedagogical Knowledge (TPK):** This component includes understanding the existence, components, and capabilities of diverse technologies as they are employed in educational environments.
- **Pedagogical Content Knowledge (PCK):** This component refers to the knowledge of pedagogy that applies to the teaching-specific content.

Therefore, based on the previous key knowledge components, the TPACK model describes the continuous improvement of lecturers as essential to design useful constructivist educational environments through the integration of ICT (Naziri et al., 2019). Its goal is the creation of new scenarios that could improve teaching-learning processes using ICT through the analysis and enhancement of the interactions between technology with contents and pedagogical methods. Both TPACK and complementary frameworks such as CoI can benefit from each other, fostering a constructivist perspective of knowledge focused on the student and using ICT (Shea & Bidjerano, 2009).

TPACK establishes a framework where the need for technological competences is included in the content and pedagogical knowledge teachers should cultivate. Aligned with this fact, previous research performed at ULPGC shows that teachers do not present resistance when incorporating ICT into their lectures (Castro Sánchez & Chirino Alemán, 2011). Through a 5-point Likert scale, they expressed their positive opinion on ICT as a supporting resource for attendance-based teaching, showing how parameters such as materials accessibility and communication were significantly enhanced. However,

teachers' satisfaction with the use of ICT, such as videos, is associated with their level of digital competence (Pattier & Ferreira, 2022).

DigCompEdu: European Framework for the Digital Competence of Educators

The European Framework for the Digital Competence of Educators (DigCompEdu) is a scientifically sound framework that describes what it means for educators to be digitally competent (Bilbao Aiastui et al., 2021). It was developed by the European Commission's EU Science Hub to address the rapidly changing demands faced by educators about digital technologies. The main objective of DigCompEdu is to offer a universal reference structure that will assist in enhancing digital abilities specific to educators across Europe. This framework is aimed at educators working in all levels of education, starting from early childhood to higher and adult education, including general and vocational training, special needs education, and non-formal learning contexts (Redecker & Punie, 2017). This framework addresses six working areas, as shown in Figure 7, adapted from (European Commission, 2022a). Overall, these areas evaluate a total number of 22 competences that are relevant to digital competence in education (Ghomi & Redecker, 2019; Redecker & Punie, 2017).

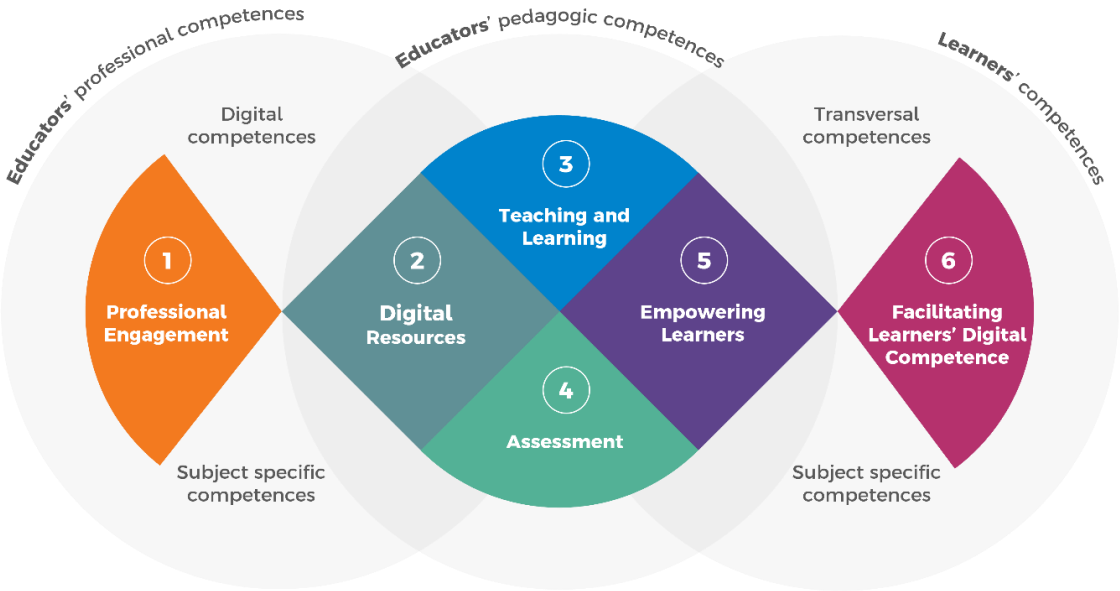


Figure 7. Conceptual areas of DigCompEdu, adapted from (European Commission, 2022a).

From all of them, a selection is presented hereafter of the competences that are relevant for the successful creation and integration of digital resources, such as videos, in educational settings:

Area 2: Digital Resources

- **Selecting digital resources:** This includes using different websites and search strategies to find and select digital resources.
- **Creating and modifying digital content:** This includes creating digital resources and modifying existing ones to suit teaching needs.
- **Managing, protecting, and sharing digital resources:** It includes effectively protecting personal data, such as exams, grades, or personal data. This might be relevant when considering video creation, to ensure the management and protection of personal data that might appear.

Area 3: Teaching and Learning

- **Teaching:** It includes carefully assessing how, when, and why to use digital technologies such as videos in the classroom with students, to ensure that they add value.
- **Guidance:** This includes monitoring students' activities and interactions in the online collaborative environments. Appropriately understanding the video consumption patterns obtained by video insights in the LMS is a helpful skill when focusing on video-based learning.
- **Collaborative learning:** Students who work in groups use digital technologies to acquire and reflect knowledge. Such technologies might include videos as a tool to foster collaborative learning (refer to the subsection 1.1.5)
- **Self-regulated learning:** It includes using digital technologies to enable students to plan, document, and monitor their learning process. Examples include self-assessments, digital portfolios for documentation and presentation, online journals/blogs for reflections, videos, etc.

Area 5: Empowering learners

- **Accessibility and inclusion:** When creating digital tasks for students, possible practical or technical difficulties should be considered and addressed. For example, equal access to digital devices and resources,

problems of interoperability and conversion, and a lack of digital skills should be addressed.

- **Differentiation and personalization:** This includes using digital technologies to provide students with personalized learning options, such as setting different digital tasks to address individual learning needs, preferences, and interests.
- **Actively engaging learners:** It includes using digital technologies to actively engage students in class or online.

Area 6: Facilitating students' digital competence

- **Information and media literacy:** It includes teaching students how to assess the reliability of information provided by any source, including educational videos found online or created by peers.
- **Digital communication and collaboration:** It includes setting assignments requiring students to use digital media to communicate and collaborate with each other or an external audience.
- **Digital content creation:** This includes setting assignments that require students to create digital content, such as videos, audio, photos, digital presentations, blogs, or wikis.
- **Responsible use:** It includes teaching students to use digital technology safely and responsibly.
- **Digital problem solving:** This includes encouraging students to use digital technologies creatively to solve concrete problems, such as overcoming emerging obstacles or challenges in the learning process.

The DigCompEdu framework aims to boost educators' digital skills at all levels and applications. By providing a comprehensive roadmap, it assists educators in navigating the digital landscape of modern education.

1.1.5 Active Learning Methodologies

Active learning methodologies are pedagogical strategies that involve students directly in their learning process, encouraging them to take an active role in their education. The focus is on creating a student-centered approach, promoting the development of higher cognitive skills (Sitthiworachart et al., 2022). These methodologies aim to give students more autonomy and

participation in their learning process, with the teacher acting as a facilitator or guide rather than as a mere transmitter of knowledge.

These methodologies have been found to positively impact students' well-being, particularly in their academic accomplishment, and in their physical, emotional, and social lives (Ribeiro-Silva et al., 2022). They also equip students with multi-competences for their professional future. These include in-class problem-solving, group discussions, peer instruction, or project-based learning, among others.

Educational technology plays a significant role in active learning methodologies, allowing for a more effective learning process. Technologies influence learning and teaching outcomes and can be used to create interactive learning environments that bring excitement to the active learning process (Sitthiworachart et al., 2022). They support students in learning and prove to be a powerful reflection tool for teachers, significant in the context of their professional development hands-in-hand with appropriate training in digital competences.

In this context, multimedia resources are a key component of educational technology in active learning. Video-based learning (VBL) denotes the knowledge or skills acquired through teaching via videos and, as explained in the subsection 1.1.2, one of their key features is the use of auditory and visual cues. The visual aspects constitute the primary source of information, and the audio is used to elaborate on such information. VBL provides unique features that make it an effective learning method that can complement and partially replace traditional learning approaches (Sablić et al., 2021).

However, though VBL is a valuable complementary resource in several active learning methodologies, further explanations are provided hereafter of those methodologies to which VBL might be a relevant tool.

- **Problem-Based Learning (PBL):** This is a student-centered pedagogy that prioritizes the learners' perspective and experience and fosters learning through problem-solving (Bermúdez Mendieta, 2021). This method can be enhanced by incorporating VBL, which presents problems through multimedia resources and interactive virtual scenarios (Noverati et al., 2020). This combination of VBL and PBL can effectively prepare students for the real-world applications of the studied knowledge. It also increases the information channels involved in the knowledge exchange and provides a learning experience more memorable for students (Sablić et al., 2021).
- **Project-Based Learning (PjBL):** PjBL is an educational approach where students engage in a long-term program, working on real-world problems to produce a measurable project outcome (Cabrera-Peña et al., 2021; L.

Zhang & Ma, 2023; W. Zhang et al., 2024). This method can be significantly enhanced by incorporating VBL, which provides visual demonstrations of the project work. The integration of VBL in PjBL not only can improve students' understanding of the project, but also increase their academic performance and their engagement in the learning process (Barrera Arcaya et al., 2022; Sablić et al., 2021).

- **Flipped Classroom:** In the flipped classroom model, students engage with lecture videos before class and subsequently participate in interactive activities during class (Baig & Yadegaridehkordi, 2023; Setren et al., 2021). This pedagogical approach empowers students to learn at their own pace, enabling them to arrive in class ready for in-depth discussions and problem-solving exercises (Nouri, 2016). The flipped classroom model has been shown to enhance student engagement, improve learning outcomes, and adapt to the evolving educational landscape (Deng et al., 2024).
- **Collaborative Learning:** It is a pedagogical approach that involves groups of learners working collectively to solve a problem or a task. There is evidence suggesting that collaborative learning can benefit both the academic performance and social skills of students (Medina Bustamante, 2021; Slavin, 2014). VBL can be used to provide collaborative scenarios that enhance the teamwork capabilities of students and their communication skills (Bhavya et al., 2022).
- **Gamification:** This pedagogical approach incorporates game elements in non-game contexts and presents numerous potentials in the enhancement of learning through an active approach (Arufe Giráldez et al., 2022; Piñero Charlo et al., 2022; Sailer & Homner, 2020). This method can be further enriched by integrating VBL, which provides engaging and interactive game scenarios. The combination of gamification and VBL has been found to improve learner motivation and engagement, thereby enhancing the overall learning experience (Murillo-Zamorano et al., 2021).
- **Thinking-Based Learning (TBL):** TBL is an educational approach that emphasizes critical thinking, problem-solving, and logical reasoning (Swartz, 2020). This method can be significantly enhanced by incorporating VBL, which presents complex concepts through visual demonstrations. The integration of VBL in TBL not only simplifies the understanding of complex concepts but also aids their retention as explained in the subsections 1.1.2. and 1.2.2.
- **Visual Thinking:** This is a pedagogical approach that leverages visual aids to facilitate learning and counting with visual supports to enhance comprehension and retention (Albert et al., 2022; Hailey et al., 2015). This method can be significantly enriched by integrating VBL, which provides

visual demonstrations of concepts. The combination of Visual Thinking and VBL not only simplifies the understanding of complex concepts but also aids in their retention (Cerqueira et al., 2023; Gutiérrez-Arenas et al., 2022; Lynch, 2022).

- **Simulation Learning:** Simulation learning involves using a model to represent real-world systems. This pedagogical approach provides an array of opportunities to practice complex skills in a controlled environment (Chernikova et al., 2020). The integration of VBL in simulation learning environments can offer realistic scenarios, thereby enhancing the overall learning experience (Nickl et al., 2022). This is also of particular interest in extraordinary learning situations such as Emergency Remote Learning (ERL) scenarios (Castro-Maldonado et al., 2021).

In conclusion, integrating VBL in active learning methodologies holds significant benefits in the overall learning process. The ability to present real-world scenarios, demonstrate complex concepts, and facilitate collaborative learning makes VBL a powerful tool in active learning environments. When further exploring and understanding its full potential, VBL is poised to transform the education landscape, making learning more accessible, engaging, and effective for all learners. However, further research is needed to optimize its creation, selection, and implementation in various learning contexts.

1.2 Video-Based Learning in STEM Education

This section aims to analyze the transformative role of video-based learning in addressing the challenges in STEM education. It explores how video-based learning can reduce cognitive load, enhancing the learning experience. This section also provides an in-depth analysis of the various formats, contents, and consumption strategies associated with videos in education. A special focus is given to the use of social media in education, particularly YouTube, discussing its opportunities and challenges. Finally, it outlines relevant criteria for the evaluation of the adequacy of videos for educational use, detecting relevant metrics for their creation or selection. This comprehensive review aims to provide a complete understanding of the current state of video-based learning in STEM education and its potential for the research line presented in this doctoral thesis.

1.2.1 Challenges in STEM Education

This section explores the multifaceted challenges in STEM education. It is mainly focused on the prevalence of abstract concepts, which often impose intense essential and germane cognitive loads on learners, making both comprehension and concept retention difficult. The persistent gender gap in STEM disciplines is also addressed; a disparity that has far-reaching implications for diversity and innovation.

Moreover, the advent of Emergency Remote Learning due to the COVID-19 pandemic has further complicated this landscape, introducing additional hurdles in delivering effective STEM education. Adequately learning from such a scenario might be helpful for future similar situations and for the learning challenges in remote and unfavorable conditions that might benefit from a digital approach.

This comprehensive examination will shed light on the complexities of both STEM education and the recent incorporation of STEAM education, paving the way for potential solutions and improvements.

Essential and germane cognitive loads

STEM areas of knowledge are often perceived as difficult due to their technical and conceptual complexity, and the rapid evolution of the technology empowering many STEM disciplines.

As has been previously introduced, a definitory challenge in STEM education is related to the wide presence of abstract concepts in their disciplines, which implies additional difficulties in learning when compared to concrete concepts (Davis et al., 2020; Yearworth, 2016). This fact imposes a higher essential cognitive load in such disciplines, as concept understanding requires a higher level of abstraction. The germane cognitive load might increase too, due to the difficulty of adequately linking the new concepts to the body of knowledge already known to the student.

This fact is connected to an additional challenge in STEM disciplines related to the difficulty for understanding the connections between the different courses and subjects. It is not only that the concepts themselves imply more difficulties to be understood, but also that courses are usually delivered in a silo-like fashion (Cabrera-Peña et al., 2021; Maciejewski et al., 2017; Shoufan, 2020). This also presents challenges in properly integrating the studied subjects in the big picture of the degree and its professional applications. Adequate

contextualization of the acquired knowledge is desirable to deal with these challenges, as well as multidisciplinary examples that strengthen the links between different courses of the degree. Moreover, practical examples of the application of the new concepts to the real-life scenario of the profession are also good ways to deal with these difficulties. Active learning methodologies such as project-based learning might be of relevance in this point.

The perceived difficulty of STEM disciplines might have significant effects on students. It can lead to higher levels of effort that overcomes the student's capacities and ends in academic stress and anxiety. Ultimately, this situation might influence students' career choices, leading to a generalized lack of motivation that ends in an increase in dropout rates (Gregori et al., 2018; Tayebi et al., 2021), and a noticeable decline in STEM vocations (Ayuso et al., 2022). The share of STEM program graduates about the total tertiary education graduates has been decreasing over the past two decades (Bacovic et al., 2022). Moreover, students who perceive STEM subjects as difficult are more likely to consider dropping out (González-Rogado et al., 2023).

The gender gap in STEM disciplines

Another significant challenge in STEM education is the gender gap. Women are underrepresented in STEM fields, particularly mathematics, physics, engineering, and computer sciences (Martínez et al., 2023; Schneegans et al., 2021). In 2018, women made up a third of researchers, and in the field of life sciences, they have achieved parity in some countries. However, women make up only 28% of engineering graduates.

Top multinational tech companies also show women's underrepresentation. As per estimations from Deloitte Global (Hupfer et al., 2021), large global technology firms were to reach up to 33% of overall female representation in their workforces by 2022, with 25% of women proportion in technical roles. For example, female employees make up between 29% (Microsoft) and 45% (Amazon) of the total workforce of the leading large tech companies in the United States (Richter, 2021). However, such representation declines when considering leadership jobs, varying from 26% (Microsoft) up to 34% (Facebook) of the total workforce of such companies. Ultimately, the share of women involved in tech jobs is even lower, with percentages between 23% (Microsoft) and 25% (Google). This is: fewer than 1 in 4 technical roles are assumed by women in these types of companies.

However, many large tech companies have made public commitments to improve their gender diversity (Hupfer et al., 2022). SAP, for example, achieved its target of having 25% of women rate in leadership roles by 2017 (Sutton, 2020), and Intel is working toward a goal of 40% women representation in technical roles by 2030 (Estrada, 2020). Amazon, for example, is also rooting for these kinds of targets to expand the number of women in senior tech and science roles by 30% yearly (Galetti, 2021). Hitachi, on the other hand, presented in 2022 that their total ratio of females in executive positions and corporate officers was 11%, and has put in place a Diversity, Equity, and Inclusion plan that aims to increase that number to 30% by 2030 (Hitachi, 2023).

This gender gap in STEM disciplines might have a complex multifactorial explanation, conditioned by personal elements such as educational background and family and social influences (Verdugo-Castro, Sánchez-Gómez, et al., 2022). A crucial aspect influencing this gender gap is related to gender roles and stereotypical beliefs that determine the perception of occupations having male or female profiles (Martínez et al., 2023; Verdugo-Castro, García-Holgado, et al., 2022). Computer science is an example of a discipline that has been socially constructed and perceived as dominated by males (Borsotti, 2018). These beliefs might be mitigated by exposure, either at home or school, and counting with appropriate encouragement from family and peers to pursue STEM disciplines in higher education (Sullivan et al., 2015). Moreover, to eradicate these stereotypes, several authors highlight the importance of counting on female role models (Heybach & Pickup, 2017; Verdugo-Castro et al., 2021).

However, the lack of referents to which new women generations might look up to is another challenge that STEM disciplines are facing. This gap is also present in the sphere of STEM dissemination. If we focus on YouTube, around 8% to 15% of STEM edutubers (educational content creators on YouTube) are female (Amarasekara & Grant, 2019; Pattier, 2021c).

In this context, the European Union included the increase in the participation of women in STEM disciplines as one of its top priorities during the last decade (Garcia-Holgado et al., 2020). In this sense, several support programs have been developed in collaboration with several organizations, such as the European Platform of Women Scientists (EPWS) or the European Association for Women in Science Engineering & Technology (WiTEC), as well as through projects such as the European Scenery on Gender and STEM (SESTEM), Gender Equality Network in the European Research Area (GENERA) and GenSET, focused on increasing the capacity for implementing gender action plans in Science. However, despite a positive tendency for women's integration in STEM disciplines, it is crucial to continue working on this path for a diverse, equal, and inclusive future.

Additional challenges in Emergency Remote Learning

In 2020, UNESCO reported that the educative centers' closure due to the COVID-19 pandemic affected an estimated 1.5 billion students worldwide (90% of the global student population) (UNESCO, 2020).

The Emergency Remote Learning (ERL) situation entailed by the COVID-19 pandemic lockdown implied additional challenges for STEM disciplines. These challenges might be summarized as concentration issues, reduced interaction, or facing learning through non-structured pedagogical methods (Tulaskar & Turunen, 2022). Some authors highlight that technology unavailability and the lack of previous experience with online learning were relevant aspects of increasing ERL impact in formal education (Aydemir & Ulusu, 2020; Muthuprasad et al., 2021; Sepulveda-Escobar & Morrison, 2020; Shim & Lee, 2020).

In this context, ICT played a crucial role in maintaining the continuity of education. However, the improvised nature of ERL hindered the development of a well-organized and structured plan that could have facilitated a complete online learning experience (Aristovnik et al., 2020; Gopal et al., 2021; Rahiem, 2020; Tulaskar & Turunen, 2022). Moreover, there are additional obstacles that could compromise the quality of education in such an improvised environment, including the lack of universal access to technological tools and the potential absence of a suitable home learning environment (Muthuprasad et al., 2021; Sepulveda-Escobar & Morrison, 2020; Shim & Lee, 2020). These factors are critical to the success of online education.

However, ERL also had a relevant impact on the well-being and mental health of students, in addition to the challenges that STEM disciplines already pose in these regards. Several studies show how this unprecedented learning situation results in a relevant increase in stress levels among students, which can also be translated into anxiety, fear, or worry among other effects (Cao et al., 2020; Li et al., 2020; Lischer et al., 2022; Wang et al., 2020; Ye et al., 2023). This situation may lead to both unfavorable effects on learning and on the overall psychological health of students (Sahu, 2020).

Considering the already existing challenges in the education of STEM disciplines, all these additional aspects due to ERL also contribute to the increase in dropout rates, the lack of motivation, and the decline in STEM vocations mentioned previously. This doctoral thesis was partially developed during a period affected by the ERL scenario due to COVID-19 pandemic in 2020, and its implications have been the object of study. The application of video-based learning as a supporting mechanism to mitigate the impacts of ERL has been included as a relevant scope.

From STEM to STEAM: a matter of art

Back in the 80s, the mathematician Seymour Papert developed the educational theory of constructionism, as explained in the subsection 1.1.1, and recognized the transformative potential of technology in education. These ideas defined the foundations from which afterward the concept of STEM was created.

Science, Technology, Engineering, and Mathematics, as has been explained, have several common characteristics that create educational challenges. This is related to the fact that these disciplines are formed upon the same fundamental body of knowledge, which presents high intrinsic and germane cognitive loads. Partially based on these ideas, together with the foundations set up by constructionism, the U.S. National Science Foundation (NSF) created in the 90s the acronym SMET, which was in 2001 substituted by STEM. However, although the concept was created in the United States, its reach is global.

The acronym STEM was created as an umbrella term to group these disciplines and is mainly used in education. The purpose of the STEM concept is to develop integrative educational models that address these challenges in the curricula avoiding silos. Therefore, this STEM education methodology provides a multidisciplinary approach to learning from early childhood education, fostering exploration, understanding, creativity, and sharing. This is usually based on teamwork, real-world application of studied concepts, learning through research and experimentation, teaching in multidisciplinary contexts, and promoting problem-solving from a critical perspective.

Aiming to increase interdisciplinary, in 2008, Georgette Yakman introduced the concept of STEAM learning, based on the integration and development of artistic subjects (A) together with scientific and technical disciplines (STEM) in a common framework (Yakman, 2008). The concept of STEAM adds another dimension to the multidisciplinary STEM idea, introducing arts as the group of the following disciplines: language arts, fine arts (or plastic arts), physical arts, manual arts, and liberal arts (encompassing social sciences). Therefore, STEAM roots towards curricular definitions that are halfway between the multidisciplinary learning of STEM and holistic learning, focusing on an interdisciplinary approach where arts add up to STEM education as a transversal element and integrator for the other disciplines.

This approach has proven to be successful from the curricular definition perspective, as well as in developing interdisciplinary projects and learning activities (Aguilera & Ortiz-Revilla, 2021; Montés et al., 2023). However, a recent systematic analysis shows that there is still no evidence backing up placing STEAM education over STEM education to promote or develop student creativity (Aguilera & Ortiz-Revilla, 2021), though the overall suitability of STEAM

education over and above STEM education is recognized. Such study showed that neither STEM nor STEAM methodologies provide conceptual clarity for researchers, academics, or educators to design, implement, and evaluate didactic interventions. Therefore, it is still necessary to develop a clear conceptual framework with broad consensus with the scientific and educational community, so that the implementation of these approaches can spread with rigorous evaluation criteria and mechanisms.

1.2.2 Reducing Cognitive Load with Video-Based Learning

As explained through CLT (see the subsection 1.1.2), there are three types of cognitive load involved in the learning process: intrinsic, extraneous, and germane cognitive loads. CTML offers insights into how multimedia resources might be helpful in the reduction of some of these cognitive loads. Particularly in the case of STEM disciplines, which are composed of a high number of abstract concepts and are considered of a complex nature, both intrinsic and germane cognitive loads are exceptionally high. Videos could be an adequate ally as didactic resources due to their ability to reduce extraneous cognitive load and contribute to some extent in dealing with intrinsic and germane cognitive loads.

Regarding the intrinsic cognitive load, videos might contribute to the increase in the number of information reception channels. Both visual and auditive channels contribute to the processing of information, and they have proven to be more effective working together than either of them separately. This implies a reduction in the working memory dedication, contributing to the processing of information and, as there is only a limited amount of processing capacity available for an individual, contributing to learning (Mayer, 2014, 2017; Mutlu-Bayraktar et al., 2019). Softening cognitive demands on working memory, using materials such as didactic videos, is associated with an enhancement in the retention and transfer of learning (Xie et al., 2017).

But, when facing a complex discipline where the intrinsic cognitive load is high, the main aspects that can be influenced by the instructional design to obtain a positive impact on processing capacity are the reduction of extraneous cognitive load and the fostering of generative processing (Mutlu-Bayraktar et al., 2019; Xie et al., 2017).

The extraneous cognitive load can be affected by an adequate pedagogic strategy through video-based learning. An example of an unprecedented

increase in the extraneous cognitive load could be the ERL due to the COVID-19 pandemic, which forced a methodology change without preparation. Video-based learning allows one to receive the information in a well-structured manner and fosters self-paced learning. Additionally, germane cognitive load can be reduced through a structured set of videos that escalate in level and reinforce links with concepts already known by students and stored in their long-term memory. In this regard, concept maps are a valuable tool to study the links between the different concepts composing a discipline and detect the main connections that should be reinforced through video learning (Bodzin et al., 2010; Novak et al., 1984).

Based on these principles, Mayer and Moreno (2003) proposed five overload scenarios and up to nine ways where multimedia learning could be beneficial to reduce cognitive load:

Essential processing in the visual channel

If the essential processing in the visual channel is higher than the cognitive capacity of the visual channel, then there is an overload driven by such processing demands. This scenario can be dealt with an off-loading strategy, trying to move some essential processing from the visual channel to the auditory channel.

An example could be a video in which all the explanations are provided by images and texts, which might cause a visual overload. If texts are substituted by a narrating voice that describes the content synchronized with relevant visual support, then the off-loading strategy might be successful. However, it is important to bear in mind that the processing demands in both channels are not higher than the target audience's processing capacity.

Essential processing in both channels

If the essential processing in both channels (visual and auditory) is higher than the cognitive capacity, then there is an overload driven by such processing demands. In this case, the essential cognitive load cannot be reduced because it is determined by the contents' complexity. Moreover, it cannot be distributed because the information is already provided through both processing channels. So, an off-loading strategy would not be helpful in this case.

Two strategies are proposed for this situation: segmenting or pretraining. On the one hand, by segmenting the explanation, there is some time between explanations that the learners have to process the information that they have received. This fosters a better transfer because the learner controls the lesson's segments instead of receiving them in a continuous unit. This way, self-paced

learning is enabled. On the other hand, enabling pretraining so that the learner becomes familiar with the names and characteristics of the lesson's components might be helpful. After such an introduction, students are somehow familiar with the information that they are about to learn, and the processing demands are lower.

Essential processing + incidental processing (extraneous material)

If one channel or both are affected by essential and incidental processing related to extraneous material, to the extent that such processing is higher than the cognitive capacity, there is an overload related to both essential and extraneous cognitive demands. The actions over essential processing might be equivalent to those in situation 2. However, there are some ways to deal with the demands of extraneous processing.

Two strategies are proposed for this situation: weeding or signalling. On the one hand, weeding implies eliminating the explanations or information that, even when it is interesting, is not necessarily relevant to the lesson's primary purpose. The better transfer when such extraneous material is excluded is described by authors as the coherence effect. On the other hand, the signalling strategy proposes providing cues on selecting and organizing the material. Some examples could be stressing relevant words in the speech, adding colored lines in animations, adding headings or indications when appropriate, etc. These types of signals enable better transfer through complex material.

Essential processing + incidental processing (confusing presentation)

If one channel or both are affected by essential and incidental processing attributed to a confusing presentation of the essential material, to the extent that such processing is higher than the cognitive capacity, there is an overload related to both essential and extraneous cognitive demands. The actions over essential processing might be equivalent to those in situation 2. However, there are some ways to deal with the demands of extraneous processing.

Two strategies are proposed for this situation: aligning and eliminating redundancies. On the one hand, aligning implies placing printed words near the corresponding parts of graphics to reduce the need for visual scanning. This fosters the spatial contiguity effect that fosters better transfer because it eases the understanding of the explanations. On the other hand, eliminating redundancies implies avoiding the presentation of identical streams of printed and spoken words. The redundancy effect describes better transfer when words are presented as a narration rather than with both narration and on-screen text.

Essential processing + representational holding

If one channel or both are affected by essential processing and representational holding, to the extent that such processing is higher than the cognitive capacity, there is an overload related to both essential and extraneous cognitive demands. The actions over essential processing might be equivalent to those in situation 2. However, there are some ways to deal with the demands of extraneous processing.

Two strategies are proposed for this situation: synchronizing and individualizing. On the one hand, synchronizing implies presenting narrations and their corresponding animations simultaneously so the learners don't need to hold representations in memory. This describes the temporal contiguity effect, where a better transfer is fostered. On the other hand, individualizing might be an alternative solution when synchronization may not be possible. This implies ensuring learners possess skills in holding mental representations in memory. This is known as the spatial ability effect, and individualization intends to match potentially unsynchronized multimedia design with high-spatial learners.

These nine solutions to the overload scenarios presented are based on the principles of CTML, which are key to formulating the factors defining adequate videos for educational purposes.

1.2.3 Videos in Education: format, contents, and consumption strategies

Considering previous benefits in managing cognitive load using multimedia, videos are an excellent ally for educators. Research in the pedagogical use of video resources provides evidence of its enhancement of parameters such as long-term conceptual retention (Berk, 2009), comprehension, and deeper learning (Jackman & Roberts, 2014).

Aspects such as the difficulties in establishing conceptual connections between new information and related concepts of the discipline previously stored in long-term memory may also reduce confidence and motivation. An adequate instructional design can work in facilitating these connections to foster the transfer of knowledge. Moreover, video integration in the instructional design has also the potential to not only improve motivation but also enhance academic performance, as it has been extensively documented in

the literature (Almasseri & AlHojailan, 2019; Arevalo et al., 2020; Carmichael et al., 2018; D'Aquila et al., 2019; Expósito et al., 2020; Kim & Ahn, 2018; Lo & Hew, 2019; Luna et al., 2018; Mayer et al., 2020; Prince, 2004; Shoufan, 2020; Tani et al., 2022; Tiernan & O'Kelly, 2019; Veytia Bucheli et al., 2019).

Coherently with the explanations provided by CTML, descriptive images and animations usually included in educational videos are helpful for the understanding of complex and abstract concepts, as they provide complementary meaning to theoretical explanations. Moreover, they can also be reproduced by students by incorporating such representations as a new problem-solving strategy (Asef & Kalyvas, 2022; D. Guo et al., 2020; Wu et al., 2020). Moreover, videos create interest in students' subjects of study and provide examples of practical applications of learned concepts. This promotes students' engagement and develops their critical thinking ability (D. Guo et al., 2020; Laugerman & Saunders, 2019).

But besides these benefits related to video format and content, they can also bring benefits due to their consumption strategy. Videos not only can be accessed anywhere and anytime, but students are in control of their pace. Due to this self-regulated consumption pace and the option to replay different parts of the video when some contents need to be reinforced, videos have proven to be an effective support for students' motivation and satisfaction, as well as in the reduction of academic stress and anxiety levels (Colston et al., 2017; Del Valle-Ramón et al., 2020; Fenyvesi, 2020; Wells et al., 2012). These aspects are also highly related to the dropout rates and vocation decline in STEM disciplines, which were exposed in the subsection 1.2.1.

The proactive use of video resources might create a self-motivational environment able to promote students' engagement and goal-setting through interaction with peers (Colston et al., 2017). Moreover, this feature can be positive for synchronous classes optimization when combined with active learning methodologies, as freed time in synchronous classes due to video integration (which would otherwise be used for topic introduction and resolution of basic initial questions) can now be dedicated to other activities that maximize the profitability of the class time (Brame, 2016).

Shoufan specifically highlights videos as key backup material in active learning strategies, highlighting their success in students' engagement and perception for purposes such as step-by-step learning procedures, as well as descriptive and conceptual explanations (Shoufan, 2021). An example of such methodologies could be the implementation of video-aided problem-based learning methodologies (Cabrera-Peña et al., 2021; Wu et al., 2020). Another example would be the use of instructional videos for conceptual and procedural

learning in flipped classroom strategies (Aidoo et al., 2022; Del Río-Gamero et al., 2022; Lo & Hew, 2019; Song & Kapur, 2017).

Moreover, apart from videos' contribution to conceptual and instructional learning, they are also a valuable tool for learning soft skills in STEM education, using them as a driver format in gamification strategies, as well as a supportive resource in online learning environments (Caeiro-Rodriguez et al., 2021). Videos are also helpful for the acquisition of new transversal and specific competences (Paladines-Paredes & Margallo, 2020). This is highlighted by Jackman (2019), considering that when other students or professionals are actively participating in the creation of videos it implies a contributing factor to the familiarization with specialized jargon and common practice in the discipline. This also helps to contextualize the new concepts in their practical applications as explained by professionals and fosters virtual and collaborative learning.

1.2.4 YouTube in Education: opportunities and challenges

Social media has widely contributed to the education sector during the last decades, offering new ways of sharing information and building virtual communities. It has been integrated into the education system, empowering educators and students and promoting new learning methodologies that successfully complement the instructional design. Up to 96% of students with internet access use at least one social network (Wade, 2019) not only for entertainment purposes but also to promote valuable activities related to their educational sphere. Some examples of such activities might be finding internships, sharing success stories, supporting their learning, or collaborating on national and international projects.

However, the integration of social media in education also has its challenges and detractors. Even though they are helpful in sharing information and organizing tasks, they are also associated with reducing the attention span during classes and creating distractions. However, given the current diversity of social media and content, it is up to instructors and students to provide a successful methodology for social media integration in educational activities so that their opportunities and benefits can be put to good use. Aligned with this reasoning, an increasing trend of adopting social media in schools is emerging, leveraging the fact that students already spend a significant amount of time on these platforms outside of school hours and that it is a preferred environment for the new student generations.

Considering all social media, YouTube is currently one of the world's largest most significant search engines. It has become an integral part of the digital educational landscape. YouTube is currently the primary source of online videos for education (Barrot, 2021; Černá & Borkovcová, 2020; García-Jiménez et al., 2020; Kohler & Dietrich, 2021; Pattier, 2021b; Shoufan, 2021; Yang et al., 2022). It is an effective educational resource, providing an audiovisual content-delivery tool for many flipped, blended, and online classes. Using YouTube, an instructor can provide multimedia material for reference, to thoroughly study and retain the information. Moreover, students can re-watch YouTube videos as often as needed, making it a powerful tool for learning, revision, and examination preparation. Apart from allowing instructors to upload their videos for their students, it also provides a vast resource library for various subjects. Notably, the role of edutubers (educational content creators on YouTube) is impacting education in a context where audiovisual content is highly demanded by this new generation of students (Pattier, 2021a, 2023).

However, YouTube also presents challenges as a search engine for educational videos. Literature highlights educators' difficulties in finding suitable videos for their academic needs (Pattier, 2021b; Shoufan & Mohamed, 2022; Tadbier & Shoufan, 2021; Tiernan & O'Kelly, 2019), as well as students' problems in choosing adequate videos for complementary self-directed learning (Mohamed & Shoufan, 2022). The suitable search of YouTube videos for education is complex, not only because of the huge number of videos published on the platform (Fyfield et al., 2021) but also because of the popularity-driven search and recommendation algorithm of YouTube (Bärtl, 2018; Ciampaglia et al., 2018). According to a recent review on the educational use of YouTube, almost 81% of analyzed videos for potential educational use fall into the "poor quality" category (Shoufan & Mohamed, 2022). Furthermore, learners tend to select their reference videos from the top of the search list (Mohamed & Shoufan, 2022), which increases the challenge of appropriately delivering adequate videos to students as a pedagogical aid. However, the platform also hosts a large number of high-quality videos in a wide variety of knowledge domains (Černá & Borkovcová, 2020), which suggests that developing suitable selection criteria from the educators' perspective is crucial.

This is when educators' digital competences become especially relevant. Several authors have pointed out the role of educators as content facilitators instead of only content creators, acknowledging the real challenge of selecting adequate channels and videos when using video-based education fostered by online available content (Černá & Borkovcová, 2020; Tadbier & Shoufan, 2021). The challenge focuses on educators being able to create or select videos whose format and cognitive load are appropriate for students' and courses' needs (Pattier, 2021b; Tadbier & Shoufan, 2021; Tiernan & O'Kelly, 2019). This is not

straightforward due to the excess of information and unregulated content. Some indications on how to evaluate the adequacy of videos for educational use are provided in the subsection 1.2.5. The adequate selection of videos by educators would serve to avoid the potential adverse effects of resorting to YouTube videos for educational purposes, such as attention reduction or the possible lack of scientific rigor (Beltrán-Pellicer et al., 2018; Zureick et al., 2018).

As mentioned in the subsection 1.1.4, the TPACK framework describes the need for lecturers to continuously improve their knowledge, with a view to the successful integration of ICT in educational environments. Educators must improve their technological competences, as well as their pedagogical knowledge to develop successful ICT-aided instructional designs. Moreover, the DigCompEdu framework (see the section 0) also describes how the adequate use of digital tools, particularly didactic videos, is tightly linked to the educators' digital competences (Guillén-Gámez et al., 2023; Guillén-Gámez et al., 2024; Pattier & Ferreira, 2022; Redecker & Punie, 2017). In this context, Zachos *et al.* (2018) acknowledge negativity towards new processes when referring to online social networks' interaction in higher education. However, they also offer broad evidence on their positive contributions as didactic complementary tools, as Yadav *et al.* (2017) also highlight. Aligned with this fact, previous research performed at ULPGC shows that educators do not present resistance when incorporating ICT into their lectures (Castro Sánchez & Chirino Alemán, 2011). Using a 5-point Likert scale, they expressed their positive opinion on ICT as a supporting resource for attendance-based teaching, showing how parameters such as materials accessibility and communication were significantly enhanced. However, educators' satisfaction with the use of ICT, such as videos, is also associated with their level of digital competence.

Aligned with these facts, and with the previously mentioned benefits of video use in education, several authors specify that motivation and engagement rates are increased when integrating ICT in higher education, as is the case of using social media for educational purposes (Gil-Quintana et al., 2020; Jackman & Roberts, 2014; Pattier, 2021b; Shoufan, 2021). Whether Lee and Lehto (2013) acknowledged that students and educators might not easily recognize YouTube's didactic value due to its focus on entertainment, YouTube is still the primary reference when considering social media for video-based education. During the last years, its popularity has increased for such purposes, even to the point that some authors highlight that edutubers might become the preferred academic reference for students due to the communicative characteristics of YouTube videos, as well as their interaction with the audience (Gil-Quintana et al., 2020).

Additionally, the connective nature of YouTube makes it an interesting candidate to promote social skills building in students through interaction and discussions, also promoting connectivism under the umbrella of the CoI paradigm (Dubovi & Tabak, 2020; Yadav et al., 2017).

1.2.5 How to evaluate the adequacy of videos for educational use

Given that most videos available online have not been explicitly created for pedagogical purposes, one of the main challenges of video-based learning is being able to appropriately select adequate didactic videos. The CTML provides valuable insights into what aspects of multimedia define the reduction of cognitive load in the learning process (see the subsection 1.1.2). Brame's research suggests that it is crucial to correctly measure the cognitive load of recommended didactic videos to promote easy-to-follow content, boost active learning linked to those resources, and maximize student engagement (Brame, 2016). Tadbier & Shoufan (2021) suggest the creation of trustworthy rankings that could be useful to aggregate didactic YouTube channels.

Previous works have researched which parameters motivate students to like or dislike educational videos, which are mainly related to the explanation quality, audiovisual presentation, and interest generated (Pattier, 2021a; Shoufan, 2019). Other authors suggest the use of rubrics or catalogs as guidelines for adequate video selection, both for educators' individual use and to create those rankings that could be shared with the teaching community (Morain & Swarts, 2012; Romero Tena et al., 2017). The main metrics proposed in the literature for evaluating the appropriateness of online videos for educational use are focused on content adequacy, format adequacy, and presentation style. They mainly point to aspects such as explanation quality, audiovisual quality, contents' technical level, rhythm, efficient length, voice and language, or interestingness (Appavoo et al., 2015; Beautemps & Bresges, 2021; Buitrago & Torres Ortiz, 2022b; Carmichael et al., 2018; Girón-García & Fortanet-Gómez, 2023; Lee & Lehto, 2013; Mayer et al., 2020; Morain & Swarts, 2012; Pattier, 2022; Romero Tena et al., 2017; Shoufan, 2019; Tadbier & Shoufan, 2021).

At this point, it is worth mentioning that the parameter of video length is crucial, but it will be dependent on the complexity of the concepts to be taught. Therefore, video length should always be tied to an optimal explanation, and the result will be a video with an efficient length. Several authors highlight the importance of video length for videos to be considered engaging. This is

directly related to the retention rate, which measures the average percentage of the video that the audience has effectively watched.

Doolittle *et al.* (2015) found, as part of their study on 212 undergraduate students, that shorter instructional tutorials promote engagement and, therefore, learning. This is also aligned with findings by Guo *et al.* (2014) for MOOC environments. Furthermore, Pi and Hong (2016) performed an eye-tracking analysis to reveal when mental fatigue appears while watching educational video podcasts. They concluded that mental fatigue started at 10 minutes and peaked at 22 minutes and recommend keeping videos shorter than 10 minutes whenever possible. Altman and Jiménez (2019) also relate video length to retention rate, concluding that videos with low retention rates could possibly increase audience engagement by shortening their length. However, as mentioned before, it is essential to keep in mind that such videos' contents strictly condition the possibilities for shortening. Related to this, Shoufan (2019) appeals to the concept of efficiency in explanations, by addressing the videos' topics directly and concisely, rather than just shortening the video to meet a numerical video length target. Additionally, regarding other YouTube video metrics such as likes and dislikes, Shoufan and Mohamed (2017) concluded that video length did not correlate significantly.

It is also relevant to remember CTML principles for a video to be optimal as a learning resource. Based on these principles, videos should contain words and pictures (multimedia principle), aligned in time to provide complementary meaning (contiguity principle). Words should not be presented both in text and audio (redundancy principle); instead, they are better presented as audio narration whenever possible (modality principle). It is also important to only provide relevant content and resource images because using other materials might make learning difficult (coherence principle). Explanations about complex topics benefit from dividing the content into different sections in a clear structure or even dividing the video into a series of videos that work together in the creation of a common body of knowledge (segmenting and pretraining principle). And, the presentation of the video should be conversational, including efficient and engaging explanations, and counting with the presence of a presenter on camera (personalization principle).

Summary of relevant metrics

Based on the previous analysis of current literature, this doctoral thesis proposes a summary and organization of the most relevant metrics to evaluate if a video is adequate for didactic purposes. They are divided into four

categories: content, explanations, visualization, and format. Figure 8 presents a concept map summarizing this proposal.

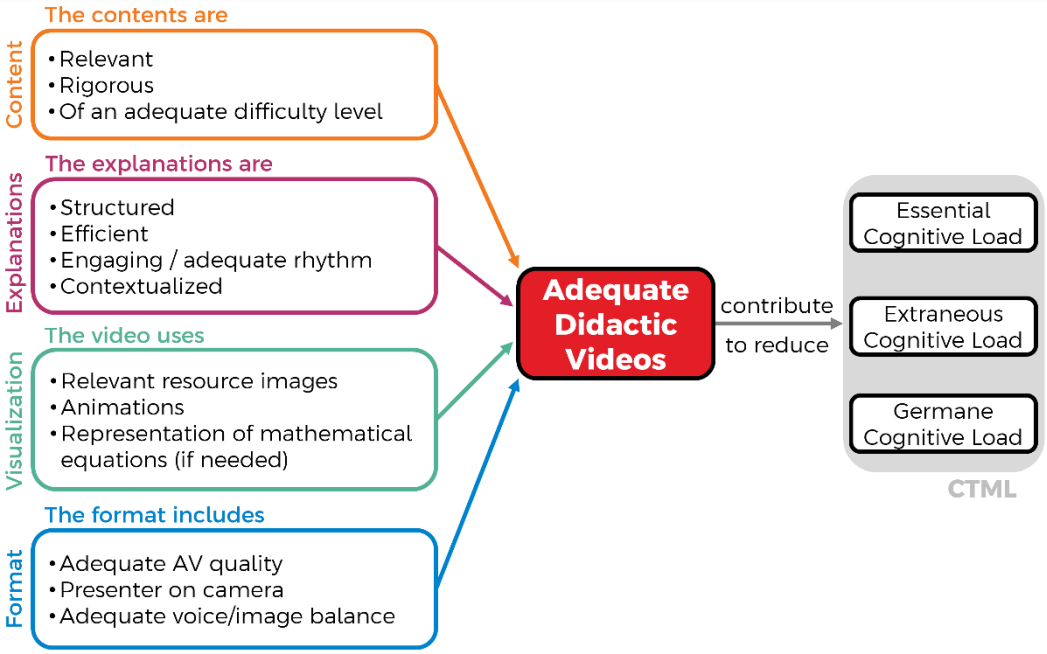


Figure 8. Concept map of the key metrics for the selection of adequate didactic videos.

The consideration of all the abovementioned metrics and factors will contribute to the reduction of the cognitive load in learning. They are further explained hereafter:

- **Content adequacy**: The videos' content should be relevant to the topic's objectives, avoiding distractions or unrelated facts that do not contribute to its understanding. It should also be truthful and rigorous for the video to be valid as a source of information. Finally, the difficulty level of its content should be adequate for the target audience so that they can appropriately learn from the video.

- **Explanations adequacy**: Moreover, explanations should optimize the transfer of contents. They should be structured, including the objectives of the video at the beginning, and finishing with a summary of key takeaways. Clear sections should be put in place for complex topics so that a gradual understanding of the topic is achieved. And, if needed, the contents can be distributed in a series of videos that escalate in level and are interconnected in a shared context.

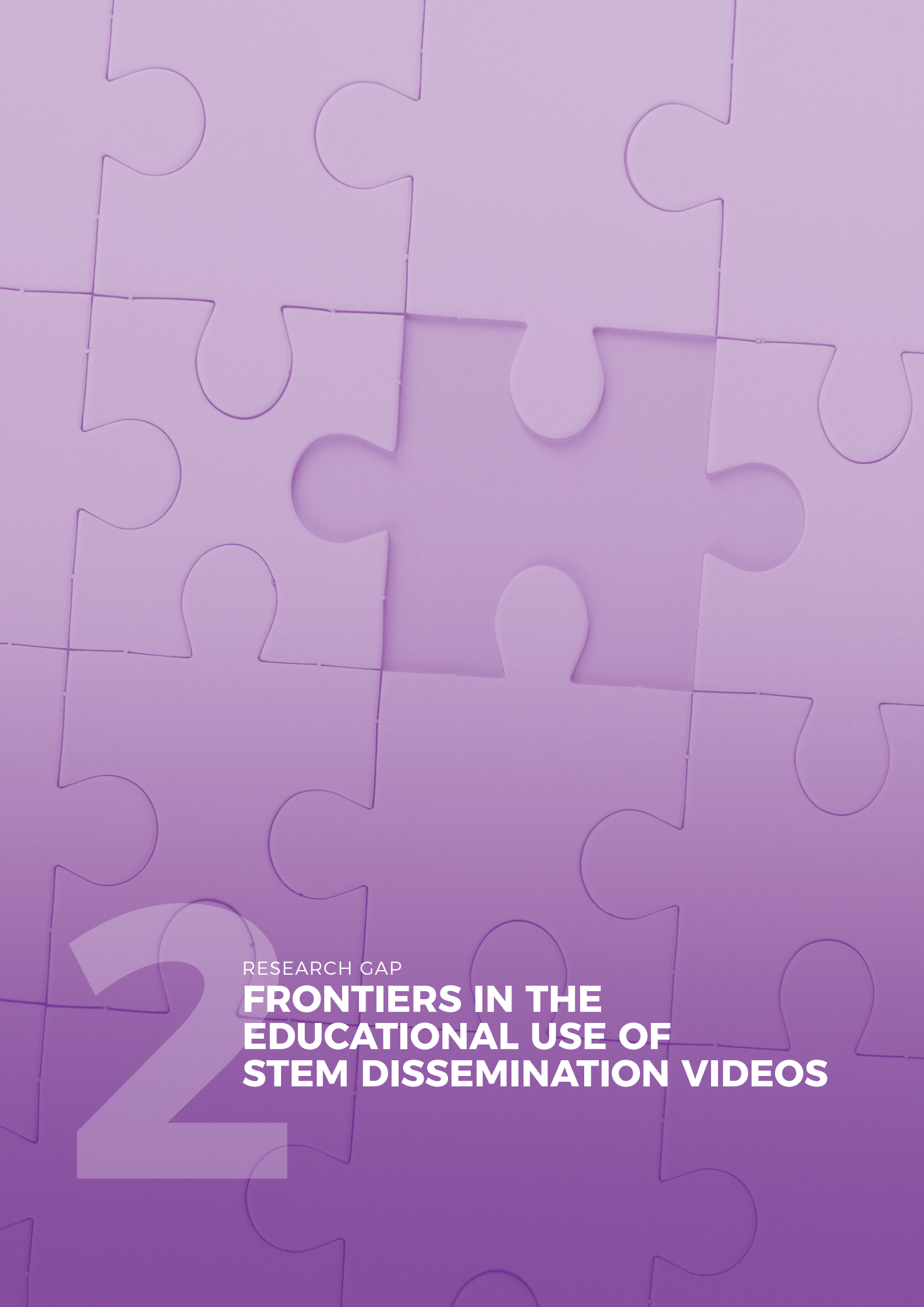
  Explanations should also be efficient, ensuring that the video clearly explains the topic avoiding repetitions and over-explanations. The video length should be as short as possible for a clear explanation, achieved

through efficient content delivery. The communicative voice should also be engaging and conversational, guaranteeing that the video is easy to follow and enjoyable for the audience. And, finally, the explanations should be briefly contextualized into the broader picture of the discipline and its relevant foundations, so that the audience can appropriately link the explained concepts with their previous knowledge stored in long-term memory.

- **Visualization adequacy**: For the video to be effective as a learning tool, it should not be limited to only explaining concepts through words, but such explanations should also be properly visible. Therefore, an adequate video for educational purposes should use relevant resource images to illustrate the concepts with real-life representations, and suitable animations to visualize abstract concepts and processes. These visual representations provide additional meaning to the explanations. Moreover, it is particularly beneficial in STEM disciplines to represent the mathematical equations related to the explanations, whenever relevant, together with a graphical representation of their meaning and the role of their variables.
- **Format adequacy**: The audiovisual format is also relevant to ensure that the video is optimized for educational purposes. The multimedia resource must have good audiovisual quality, guaranteeing that the distractions occasioned by poor audio (echoes, noise, saturation, etc.) or images (blur, pixeled image, noise, wrong framing, etc.) are minimized.

  It is also desirable to count on a presenter on camera to personalize the explanations. There should be an appropriate balance between the video portions with the presenter on camera (mainly for introductions and personalized discourses) and the portions of the video counting with resource images or animations (mainly for conceptual explanations and contextualization).

  A good balance should also be assured between the information distributed in words and the information distributed in images. Both channels of information transference should be synchronized appropriately to obtain a video with a proper combined visual and auditory explanation.



2

RESEARCH GAP

FRONTIERS IN THE EDUCATIONAL USE OF STEM DISSEMINATION VIDEOS

2. Research gaps: Frontiers in the educational use of STEM dissemination videos

After carefully analyzing the current literature, some research gaps have been detected in the interconnections between multimedia dissemination resources and their potential value and use for education in STEM disciplines. Figure 9 shows the main research gaps detected, as well as the areas already covered by literature, in the four main influential factors for the adequate integration of dissemination videos in STEM education:

- Metrics to optimize the educational value of videos.
- Potential of dissemination resources in education.
- Use of videos in Emergency Remote Learning scenarios.
- Use of videos to foster interest in STEM disciplines.

The objectives of this doctoral thesis and the research questions addressed will be aligned with these research gaps. Such objectives and research questions will be presented and developed in the chapter 3. However, it is worth noting that research is constantly evolving, particularly in dynamic and changing environments such as online communication and social media. Therefore, the section 8.2 describes the future research and research lines derived from this doctoral thesis.

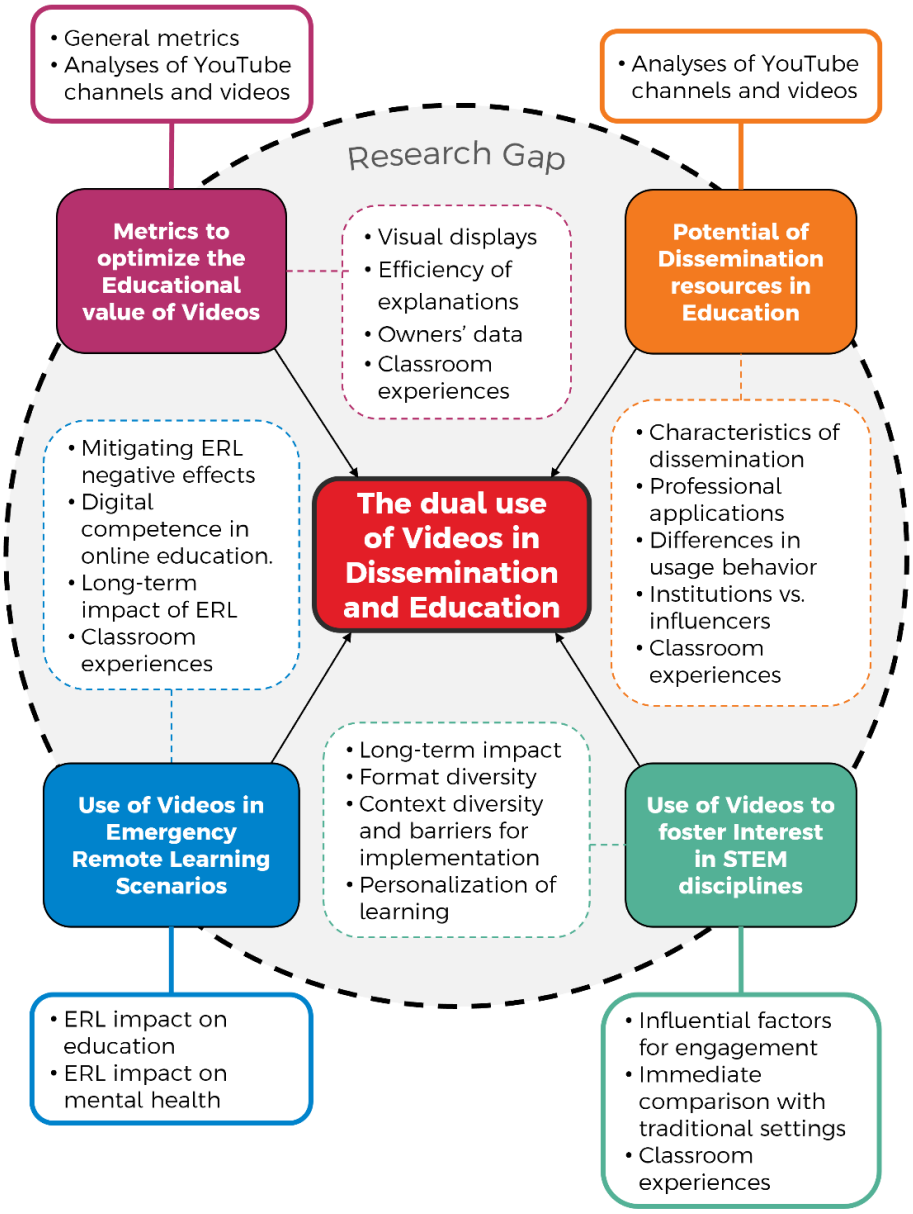


Figure 9. Concept map of the research gap detected in video use in STEM education.

2.1 Metrics to optimize the educational value of videos

The first gap concerns the need for robust metrics and rubrics to assess the suitability of existing videos for educational purposes, further exploring the summarized proposal from this doctoral thesis exposed in the subsection 1.2.5. This gap also focuses on developing real classroom experiences to validate the

impact of selected videos. While a plethora of educational content exists on the internet, how do we discern the pedagogical value of these videos?

Several benefits of videos in education have been previously exposed but, as highlighted by Shoufan and Mohamed (2022), we still don't know how these principles could be applied to the selection of YouTube videos for students, nor the optimal integration strategy in the instructional design. There appears to be consensus on the main metrics defining a good video, but still, some of them are based on perception. More evidence is required to obtain an objective pondered measurement that might act as a standard and comprehensive framework for the education community. In this line, several authors also highlight the need for new replication and comparative studies to understand the true impact of YouTube on learning (Bärtl, 2018; Saurabh & Gautam, 2019; Shehu et al., 2019; Shoufan & Mohamed, 2022).

There are instruments available to analyze educational YouTube channels, as well as rubrics for similar purposes (Lee & Lehto, 2013; Morain & Swarts, 2012; Pattier, 2022; Romero Tena et al., 2017). These instruments are mainly based on evaluating parameters related to content adequacy, format adequacy, and presentation style. However, more empirical studies should be developed in the form of real classroom implementations of these proposals. These real classroom scenarios might validate to which extent the videos selected by the abovementioned principles are having a significant impact on the learning objectives for which they are aimed.

Moreover, new research should pay more detailed attention to specific parameters that have been evidenced as particularly relevant for video use in education. Two specific parameters have been detected as crucial: the video length and the illustration of abstract concepts.

On the one hand, the video length should be as short as possible considering the suitable efficiency of the explanation, as exposed in the subsection 1.2.5. However, it is worth noting that not all bodies of knowledge require the same considerations in terms of explanations. The role of videos for conceptual aid in STEM education is mainly related to their ability to illustrate abstract and complex ideas. However, the depth of the explanations provided should be carefully selected in each case to maintain an optimal exposition and, therefore, an optimal video length concerning the complexity of the topic. More specific research should be developed focusing on the different sensitivities affecting the explanation depth in videos about different STEM topics and evaluating the impact of the resulting video lengths and explanation density on mental fatigue.

On the other hand, the illustration of abstract concepts is critical to maximize the effects of video learning in STEM disciplines, as explained in the

subsection 1.1.2. (Asef & Kalyvas, 2022; Xie et al., 2017). However, there are also different sensitivities when using visual displays during learning. First, careful evaluations should be done when visual resources are more efficient within an educational video, as well as their desired characteristics and length (Clark & Mayer, 2016). Second, it is also worth studying the impact on learning of just passively watching such visual displays versus the effects of actively reproducing those representations to understand better what is being studied (D. Guo et al., 2020; Wu et al., 2020).

Moreover, acquiring other relevant advanced parameters, such as the average view duration in a published video, is challenging. Not using owner's data when analyzing YouTube content might present some limitations, as social media data can differ depending on the collection method that is being implemented (Bärtl, 2018). Saurabh & Gautam (2019) also acknowledge this fact, remarking how channel owners count on data that third parties could not otherwise mine, and this allows deeper data acquisition and analysis. More research should be developed with the owner's information to provide the academic community with relevant information on how STEM dissemination and educational videos are being consumed.

Currently, only a few articles have been developed with information from the perspective of channel owners, which could provide helpful information on how to produce better educational videos and how to enhance video integration in the classroom. The cases described by Saurabh and Gautam (2019), Bello-Bravo et al. (2021), and Yang et al. (2022) are some of the very few available.

In conclusion, most aspects related to evaluating the adequacy of a certain video for educational purposes are extensively covered in the literature. For instance, there is consensus on the main metrics that a video should meet to be perceived as of good quality. There are also several analyses of YouTube channels and videos using public information, as well as catalogs and rubrics that might guide the teaching community. However, there are several research gaps detected in the evaluation of the adequacy of available videos for educational purposes:

- First, having a better understanding of the role of visual displays in videos for conceptual learning and how to optimize their effect in complex abstract explanations, is an area to be further explored.
- Second, the importance of the efficiency of explanations and their relation to video length and retention rate is worth studying. This implies the challenging task of finding the right balance between providing a comprehensive explanation and maintaining an optimal video duration, and detecting how such factors affect the average view duration.

- Third, there is a need to count with quality data from YouTube channels to properly evaluate the audience's behavior in front of videos with different characteristics. This would be valuable for empirically understanding the real implications of potentially relevant metrics for video adequacy. This quality information should come from owners' data, which can provide the academic community with invaluable insights.
- Lastly, there is also a need for more empirical evidence of video implications in education from real classroom experiences. This would provide a clearer picture of the impact of selected and produced videos on conceptual learning, academic performance, the generation of interest and motivation towards STEM disciplines, etc.

2.2 Potential of dissemination resources in education

Since the early 2000s, STEM dissemination has moved to digital formats, and, particularly during this last decade, the video format has grown to become one of the most popular ways to disseminate. Free access videos available on the internet, with their singular characteristics (including resource images, animations, audio, on-camera engaging presenters, etc.), are a potentially suitable ally to meet the learning needs of new generations, as it has been widely explained in the chapter 1.

When referring to STEM dissemination in video format, research usually directly addresses the YouTube platform and the concept of edutubers. Indeed, the engaging voice tipically associated with edutubers has common characteristics with the communicative voice of dissemination. However, two clarifications are relevant on this point:

1. STEM dissemination is also done in video format outside of YouTube's borders.
2. The fact that there is a video on YouTube sharing information about STEM disciplines does not mean that it is a dissemination resource.

Therefore, in this doctoral thesis and the academic articles associated with it, the concept of "dissemination" will be considered and used as such to clearly point out its specific characteristics and intention. However, even though there is a lot of research focused on the educational use of YouTube, there is still a

lack of a formal approach to the characteristics of public dissemination; the preface of this document further elaborates on this issue.

There are still many prejudices in the academic community concerning public dissemination, particularly regarding the parameters of rigor and content quality (Buitrago & Torres Ortiz, 2022b; Vizcaíno-Verdú et al., 2020). These prejudices are mainly based on the lack of peer-reviewed mechanisms to guarantee that the information spread online is accurate enough, together with the simplifications needed to appropriately achieve the public dissemination purpose. The growing proliferation of STEM-related online dissemination content has made it easier for scientific knowledge to be shared in a format that is more accessible and enjoyable for society (Cárdenas, 2017). However, this free circulation of knowledge makes it more exposed to media noise and misinformation (Quesada Cubo & Navarro Ardoy, 2023). This is one of the challenges that public dissemination is currently facing.

However, it is undeniable that these resources exist, and they are demanded and widely used. Not in vain, Gil-Quintana et al. (2020) documented how edutubers might be a preferred academic reference for students. This is due to some of the characteristics of the communicative style used by disseminators and edutubers and their high engagement rates and interaction with the audience. It is true that the free circulation of ideas online opens a room for pseudoscience content and manipulation. Still, the challenge of public dissemination is to deal with this scenario and provide interesting, engaging, and rigorous information. In this line, dissemination materials might also be invaluable as didactic resources. There is still a need for more research focused on the trends in dissemination, and how to foster these synergies towards the education sector.

Moreover, the fact that a high quantity of dissemination resources is developed by active professionals or institutions, is positive in the acquisition of transversal skills. Students can benefit from this fact because it is a valuable way to empathize with others currently working in the same field in which they are being trained, acquiring new virtual role models. Such role models will show them professional applications of their degree, and real-life examples of the concepts they are studying. Additionally, the fact that other students or professionals create videos also reinforces the familiarization with specialized jargon and common practice, and fosters virtual and collaborative learning (Jackman, 2019). The utilization of videos as a practical tool not only enriches the comprehension of the implications and applications of the degree but also addresses some of the primary causes of high dropout rates in STEM disciplines (Gregori et al., 2018; Tayebi et al., 2021). However, more classroom experiences will be helpful to specifically address these applications of dissemination videos elaborated by institutions, professionals, or peers.

It is also interesting to develop clear evaluations on the usage behavior of dissemination and education videos, to obtain clear insights on the parameters significantly influencing each type of video consumption. For example, it would be interesting to evaluate how parameters such as video length might be correlated with retention rate in both cases, to infer how such parameters should be considered in the creation process of dissemination materials aimed at complementary didactic use. Scarce references specifically address this aspect, which might be crucial in evaluating the compatibility between dissemination and education purposes with a unique optimized format.

Finally, it is interesting to address the differences in both purpose and format between the dissemination activity performed by influencers and institutions (Buitrago & Torres Ortiz, 2022a). The growing popularity of STEM fields online fosters the appearance of content creators in most knowledge domains. Still, it also opens an opportunity for universities and other institutions to contribute to transferring scientific and technical knowledge. However, there is a need for more research on the differences between their communicative styles, the audiovisual formats implemented, and the impact of their respective contents, as well as on the impact of the collaboration between influencers and institutions. These insights might be useful to develop new communicative strategies in institutions that enhance their reach, engagement, and overall efficacy.

In conclusion, several research gaps are still found when it comes to assessing the educational value of STEM dissemination multimedia resources:

- First, a comprehensive framework should be developed for a formal definition of public dissemination's role, characteristics, and mechanisms, as well as its synergies with education and journalism.
- Second, it is relevant to further study how the use of dissemination videos created by institutions, professionals, or peers contributes to a complete understanding of the professional applications of the degree, as well as reinforcing specialized jargon.
- Third, more research would be valuable in understanding consumption behaviors for both dissemination and educational videos. This will allow the development of compatible, optimized formats that might address both aims.
- Fourth, the differences in purpose, communicative strategies, and impact between the dissemination made by influencers or institutions should be further studied and their collaboration opportunities.
- Lastly, more empirical evidence is needed through real classroom scenarios that bring insights about the educational value of STEM dissemination

resources. This will show their true impact in parameters such as academic performance, contextualization of STEM disciplines in their real-life applications, and increased interest and motivation towards these knowledge domains.

2.3 Using videos in Emergency Remote Learning scenarios

The COVID-19 pandemic has profoundly impacted every aspect of our lives, and education is no exception. As the virus spread across the globe, schools and universities were forced to close their doors, leading to an unprecedented shift towards remote learning. This sudden transition to what we now refer to as the Emergency Remote Learning scenario has highlighted both digital education's potential and challenges.

In many ways, the pandemic has accelerated trends that were already in motion before (Facer & Selwyn, 2021; Timotheou et al., 2023). The use of digital tools and online platforms for teaching and learning was already on the rise, but the pandemic made them a sudden necessity. Teachers had to adapt their lesson plans for online delivery, and students had to adjust also to learning from home without the benefit of face-to-face interaction with their peers and instructors (Misirli & Ergulec, 2021). Therefore, the shift to remote learning also exposed and exacerbated some existing challenges and inequalities (Bonacini & Murat, 2023; Kennedy et al., 2022), from which we could highlight the following:

1. Not all students can access a reliable internet connection or a suitable device for online learning. The learning environment at home is also crucial in these scenarios, and the familiar and social situations might play a differential role (Misirli & Ergulec, 2021).
2. Not all teachers have the training and support that they need to teach effectively online. Digital competences have become crucial skills that teachers and students should be trained to face the challenges of ERL scenarios (Misirli & Ergulec, 2021). This is still an area where more research could be useful to evaluate the digital competence of academics and enhance their preparation for such educational settings.

Moreover, the impact of ERL on education extends beyond the immediate shift to remote learning. The disruption to traditional learning environments and routines has had a significant impact on students' mental health and well-

being (Lischer et al., 2022; Ye et al., 2023). Even though the direct impact of ERL on education is widely studied, the long-term effects of this disruption on educational outcomes are still unknown (European Commission, 2022b; Meinck et al., 2022; Namkung et al., 2022).

The experience of the ERL due to COVID-19 has underscored the importance of being prepared for such emergency remote learning scenarios. Digital education will continue to play a significant role in the future of education, even after the immediate threat of the pandemic has passed. Therefore, we must use the lessons learned during this period to build more resilient, inclusive, and effective educational systems.

On the other hand, regarding social demands for STEM information, the COVID-19 pandemic increased the presence of STEM content in both mass media and social media. Only in a matter of months, the number of people receiving information about such disciplines through WhatsApp, blogs, and social media increased substantially (Quesada Cubo & Navarro Ardoy, 2023). This is one of the benefits of the pandemic: the social understanding of the importance of research and STEM dissemination.

YouTube is found among the most popular social media for STEM dissemination (Černá & Borkovcová, 2020). YouTube's ubiquity in education also played a crucial role in ERL providing a vast array of educational content and allowing educators to share content with students. Moreover, the students' personal use of video for learning scientific disciplines increased substantially during ERL (Breslyn & Green, 2022). However, besides the broad understanding of videos' integration in educational contexts, specific research on the design of video-based strategies to mitigate the adverse effects of ERL would be interesting. This would benefit not only such scenarios but also learning in unfavorable situations, where STEM videos published on YouTube might complement practical lessons in contexts lacking scientific resources.

In these regards, there is also a gap in the literature when it comes to gathering empirical evidence of the use of video-based pedagogical strategies to mitigate ERL impacts. These mitigation strategies could influence the ERL's negative influence on academic performance, motivation, or interest in STEM subjects. However, comparative studies should be developed to address these parameters in ERL situations versus in traditional settings.

In conclusion, several gaps are found in the specific impact of videos during ERL scenarios. Research in this line might be useful for potential future emergency situations that force similar educational settings, as well as for unfavorable situations in remote areas that might benefit from digital access to knowledge. The gaps detected and addressed in this doctoral thesis are the following:

- First, the role of video-based pedagogical strategies that might be useful to mitigate the negative impacts of ERL is an area worth exploring.
- Second, more research is still needed on the digital competences for online education, also relevant when it comes to video integration as a didactic resource. This is applicable both from the teachers' perspective and from the students' perspective.
- Third, even though the overall impact of ERL on education and students' mental health has been widely studied, there is still a lack of research on the long-term effects of ERL in education.
- Lastly, more real classroom experiences are needed to evaluate the specific influence of videos in an ERL scenario compared to a traditional setting.

2.4 The use of videos to foster interest in STEM disciplines

Using videos as an educational tool to foster interest in STEM disciplines has gained significant attention in recent years. While several aspects of this approach have been extensively studied, there are still areas that remain underexplored.

Videos, particularly YouTube videos, have been lauded for their ability to engage students and enhance their learning experience. There is broad evidence about some of the influential factors from videos in the generation of interest and motivation towards STEM disciplines in students. This increase in student engagement through the transfer of knowledge is mainly due to an effective video design based on the use of graphics, the presence of a virtual instructor, and an optimized video length. These aspects have also been extensively covered in the section 1.2.

Most studies base the affirmation that videos are an effective complementary format to foster interest in STEM disciplines on the direct comparison with more traditional educational settings with texts and regular lectures as the source of information (Kayan-Fadlelmula et al., 2022; Li et al., 2020). However, there is a lack of research on the long-term effects of these interventions. It is crucial to understand whether the initial interest sparked by these videos translates into a sustained engagement with STEM subjects over time. This could involve tracking students' academic performance, career choices, and

overall attitude towards STEM disciplines in the years following the intervention.

It has also been found that the consumption of content related to STEM disciplines is positively associated with an increase in the interest of students towards STEM degrees when starting university (Chen et al., 2023). This applies to the influence of such content from mass media and social media, as well as from playing video games related to STEM. Current studies highlight the indirect mechanism of influencing career interests through the personal values system and identity formation. However, more research is still needed on the nature of such influence and the comparative effects depending on the tool type and format used.

Moreover, the context in which students are involved is also a determining factor in developing such interests in STEM disciplines. Most of the existing research is usually conducted in specific contexts based on certain countries or school settings (Kayan-Fadlelmula et al., 2022). However, the influences of the students' familiar and social context, as well as their culture and educational system, might be relevant factors in understanding how interest and motivation towards STEM disciplines are developed and, hence, how dissemination videos might impact these aspects.

These diverse contexts might present barriers to the implementation of video-aided education in some real-world educational settings. Such barriers might be directly related to technical issues, lack of resources, or resistance from educators. Some of these challenges are also partially covered by the previously declared research gaps when addressing the needs of the teaching community to develop their digital and technological competencies, and when addressing the particularities of education in unfavorable contexts. However, these are aspects also impacting the potential of video-based learning to positively impact students' interests in STEM disciplines in such contexts, and there is room for more research to be developed addressing such needs.

And finally, the advancement of technology in the context of education has generated an increasing interest in personalized learning and how to address the individual interests and learning needs of students (Tetzlaff et al., 2021). Educational technology plays a crucial role in addressing learner variability and facilitating the advancement of personalized learning. The aim is to allow learners to set specific learning goals, select instructional approaches and content, as well as select the learning activities and pace that are suitable for their needs and interests (Zheng et al., 2022). In this context, educational videos offer promising applications and opportunities in personalized learning, as they can be tailored to meet specific learning needs and interests of students (Bernacki et al., 2021). Yet, more research is still needed to fully understand

the role of videos in creating effective video-based instructional designs for personalized education. This is an area of work facing several challenges such as a lack of a common approach and definition of what personalized learning should entail (Shemshack & Spector, 2020), the complexity of personalized learning designs that attempt to accommodate all learners based on several characteristics, design elements, and ends (Bernacki et al., 2021), and the intense resource requirements needed for its suitable implementation.

In conclusion, the role of videos in the development of interest and motivation towards STEM disciplines encompasses some areas still worth studying:

- First, it would be interesting to understand further whether the impacts of video-aided learning on interest and motivation are sustained over time.
- Second, more research is still needed on the specific and comparative impact of different formats and tools, such as mass media, social media, video games, etc.
- Third, the context diversity into which video-based learning methodologies could be implemented, and the potential barriers to its implementation, are still areas requiring further research.
- And, lastly, the concept of personalized learning, and the role of videos in it, present numerous challenges in pursuing an individualized approach to students' needs and interests.

3

RESEARCH STRATEGY

OBJECTIVES, METHODOLOGY AND TIMELINE

3. Research strategy: Objectives, methodology and timeline

This chapter outlines the overall research strategy designed for this doctoral thesis and executed throughout its duration. It starts by presenting *Sígueme la Corriente*: a singular case of a STEM YouTube channel that has served as case study in this research. The chapter defines the objectives and research questions that guided the investigation, providing a roadmap to shed light on the previously detected research gaps. Finally, the methods and materials used in this research are presented, explaining the research design followed to ensure the findings' validity, reliability, replicability, and reproducibility.

3.1 *Sígueme la Corriente*: combining educational and dissemination purposes

As exposed through the chapter 1, the use of dissemination videos widely available online might benefit STEM education. There are multiple YouTube channels specialized in publishing dissemination videos about different knowledge domains, which can be accessed by educators and students worldwide.

The reference example for this doctoral thesis, on which the research is based, is the STEM YouTube channel *Sígueme la Corriente*[20] (Lijo, 2017). *Sígueme la Corriente* is a popular Spanish-speaking YouTube channel focused mainly on energy, electricity, and sustainability. It was created in January 2017, and since then, the channel has published a total of 150 videos, reaching more than 170.000 subscribers and 5,500,000 views (see Figure 10). Since then, three main phases have taken place in its evolution: presentation, consolidation, and reconceptualization (see Figure 11).

Sígueme la Corriente's initial presentation stage lasted about two years, until April 2019. During this time, the channel focused on creating awareness

[20] https://youtube.com/SiguemeLaCorriente (Accessed 05/04/2024)

about energy, electricity, and sustainability through specialized content combined with videos about other general STEM topics. The channel's author also appeared on TV and radio shows and participated in various national and regional events to reach a wider audience.

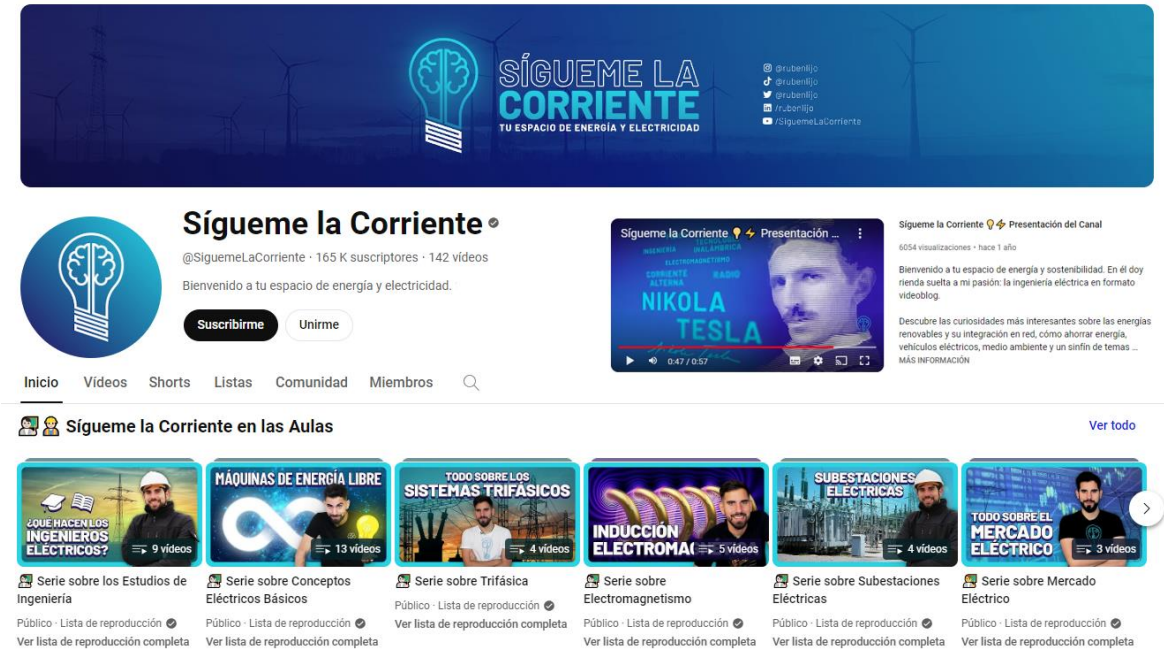


Figure 10. Illustrative image of *Sígueme la Corriente* YouTube channel.

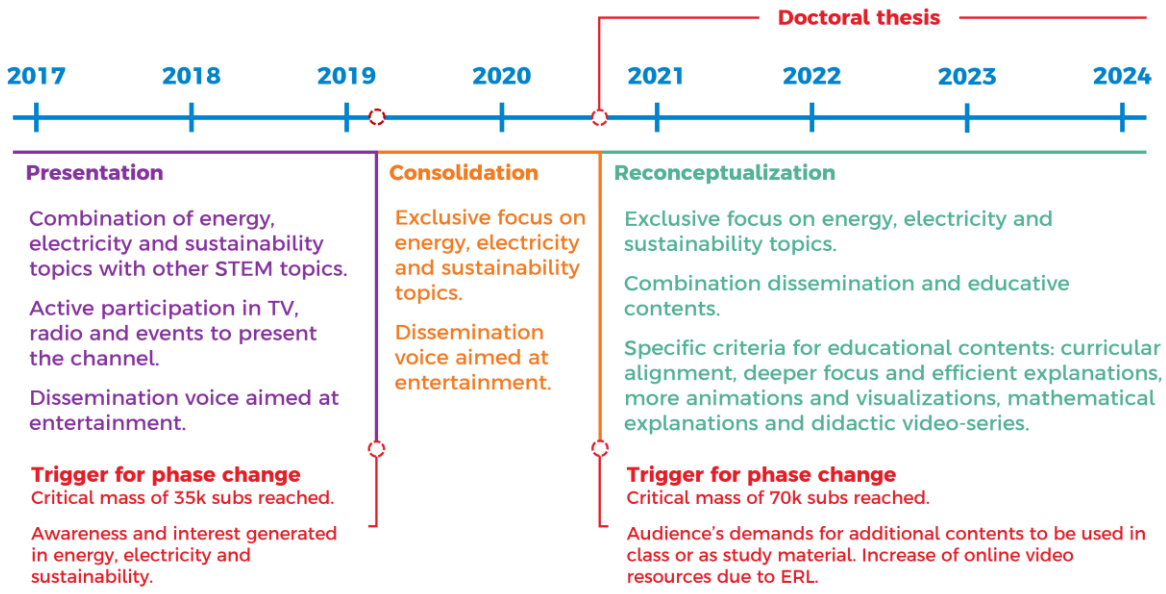


Figure 11. Timeline of Sígueme la Corriente phases and their triggers.

From April 2019 to August 2020 the consolidation stage of *Sígueme la Corriente* took place. This stage focused on creating exclusively new content related to energy, electricity, and sustainability while maintaining the dissemination voice aimed at entertainment. Through this stage, the channel's subscribers and views increased significantly, and demand grew for additional content that could be used in class or as study material. This coincided with the first stage of Emergency Remote Learning (ERL) that arose due to the COVID-19 pandemic.

Furthermore, due to the channel's wide use in educational contexts, a reconceptualization phase started in August 2020 with the creation of a specific series of videos dedicated to serve as pedagogical aids. These videos aim to be integrated both into technological branches of secondary education and into energy, electricity, or sustainability-related university degrees.

All the channel videos have been categorized by a functional criterion, discretizing between "dissemination videos", "educational videos", and "others" for announcements, shorts, or non-energy-related videos (developed during the presentation stage). The total number of videos published during this six-year time frame in each category is 29 in education, 62 in dissemination and 56 in others. These categories were set by intentionality. On the one hand, "dissemination videos" aim to entertain the audience and satisfy their curiosity by presenting interesting and engaging topics. No specific constraints are considered in this category regarding topic selection or format definition. These are the videos that have been published in the channel since its origins, and some examples of their titles would be: "How can you understand your electricity bill?", "How is Energy produced in the Matrix movies?", or "Could you be saved if a lightning strikes you?".

As opposed to dissemination contents, educational contents in the channel are differentiated by the following specific features, following the guidelines and consensus in the literature about the features that optimize knowledge transfer in multimedia formats:

- Therefore, they are aligned with the content of STEM degrees. Concept maps have been helpful in this regard to adequately select the topics from the curriculum that could most benefit from video-aided reinforcement.
- They count on a deeper focus and more efficient explanations when compared to dissemination videos, and the communicative voice avoids the distractions that otherwise would aim for entertainment.
- The use of animations and visualizations in educational videos is intensified and specifically tailored to support the learning of complex, abstract concepts.

- The mathematical explanations of explained ideas are explicitly included and clarified as part of educational videos when relevant.
- These educational videos are often part of a more comprehensive series, linking new contents to prior knowledge and creating a structured sequence of videos that increase in complexity.

However, besides the reconceptualization stage aimed to create such educational resources intentionally, some previous contents were detected also to be compliant with the established criteria to fall under this category. From the presentation and consolidation stages, only a share of 24% could be considered educational, whereas during the reconceptualization stage such share was set at 50% (excluding the "others" category from consideration in both cases). Educational contents in the channel respond to specific pedagogical requests from the audience (both students and teachers) and has been integrated into educational environments (either in secondary or university education). Moreover, with the development of the educational video category in the channel, agreements with universities have taken place to produce specific videos or video series.

After more than eight years since the creation of *Sígueme la Corriente* and more than four years since the reconceptualization stage, *Sígueme la Corriente* has become a singular case of a STEM YouTube channel with dual purpose towards dissemination and education. This doctoral thesis has documented and analyzed such a process as a means of further understanding the intersection between the purposes of dissemination and education, and the educational use of dissemination resources.

3.2 Objectives and Research Questions

The fact that this doctoral thesis counts with the owner's data for a relevant STEM YouTube channel such as *Sígueme la Corriente* has allowed the pursuit of three interesting Research Objectives and eight Research Questions that directly address the research gaps detected through the literature examination (chapter 2). Therefore, and aligned with such research gaps detected, three Research Objectives (RO) and eight Research Questions (RQ) have been defined as guidance for this research. Figure 12 shows the intersection of the research lines of this doctoral thesis (determined by the research gaps) and the different RO and RQ to be addressed. They will be further presented in the following subsections.

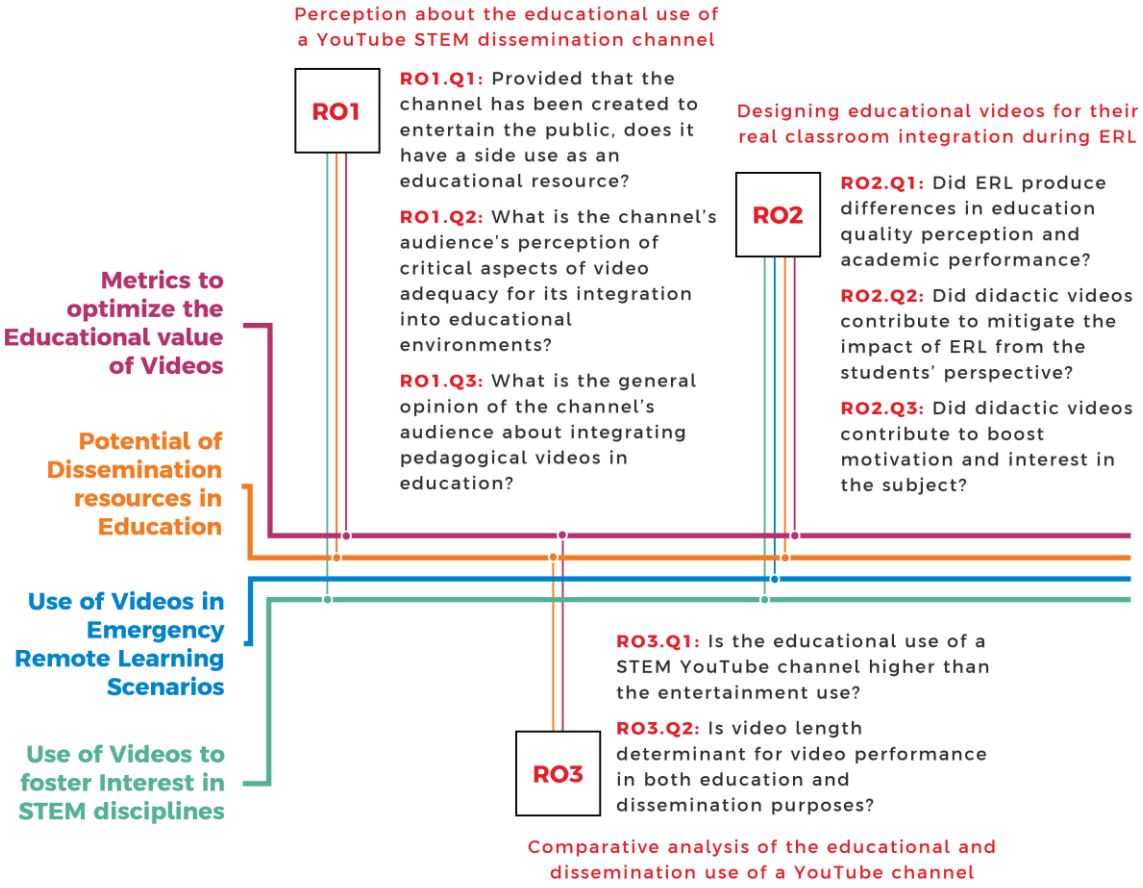


Figure 12. Research lines, objectives and questions involved in this doctoral thesis.

It is worth mentioning that while the incorporation of both STEM and STEAM education is interesting as educational approaches, this doctoral thesis does not focus on those methodologies themselves. Instead, attention is placed on the common challenges found in the conceptual learning of science (S), technology (T), engineering (E), and mathematics (M) disciplines. Therefore, the STEM acronym is used in this document to refer to those disciplines in analyzing these challenges for conceptual learning and studying how video-based learning might be beneficial.

3.2.1 RO1: Perception about the educational use of a YouTube STEM dissemination channel

The first objective set in this doctoral thesis was designed during early 2020, with the COVID-19 pandemic increasing the need for online resources that could be used as pedagogical aid during ERL. In that period, *Sígueme la*

Corriente was not regularly publishing videos designed explicitly with educational purposes. Instead, the channel was mainly focusing its content on entertainment and dissemination. However, despite that fact, some comments suggested that such videos were being used both by students and teachers.

Therefore, the first objective (RO1) set in the doctoral thesis was to better understand the potential pedagogical use of an informal dissemination YouTube channel through characterizing its audience. The objective was set to assess whether the audience was using the channel for educational purposes, even though its aim was entertainment. Proven that such educational use exists, another research question intends to evaluate whether key metrics for the adequacy of educational videos were met by the channel's contents, according to the audience's perception. Finally, a last generic research question focused on the general perception of the audience about the implications of integrating videos in formal education.

Consequently, the specific research questions contributing to the RO1 are:

- **RO1.Q1:** Provided the channel has been created to entertain the public, does it have a side use as an educational resource?
- **RO1.Q2:** What is the channel's audience's perception of critical aspects of video adequacy for its integration into educational environments?
- **RO1.Q3:** What is the general opinion of the channel's audience about integrating pedagogical videos in education?

As reflected in the Figure 12, this RO is aligned with the following research lines: Metrics to optimize the educational value of videos, the potential of dissemination resources in education, and the use of videos to foster interest in STEM disciplines.

3.2.2 RO2: Designing educational videos for their real classroom integration during ERL

The second objective of this doctoral thesis continues from the confirmation that the contents of the channel were being used for educational purposes, even though that was not their objective. This fact might illustrate how informal dissemination contents were being integrated as part of formal education, either by teachers' active introduction of such resources in their classes or by students' seeking conceptual support online. In any case, given that there is demand, it would be interesting to examine the effects of creating content

specifically aiming for an educational use, whose features are optimized for such purpose.

Moreover, this objective was aligned with a specific need in the BSc. Degree in Electrical Engineering from the School of Industrial, Aerospace, and Audiovisual Engineering of Terrassa, at *Universitat Politècnica de Catalunya*. In the transition to ERL due to COVID-19, the students were facing a bottleneck in the subject "Electrical Machines I" for the concepts of electromagnetism and 3-phase circuits; since they are contents that were not appropriately explained in previous subjects and constitute the building blocks of 32.2% of the courses composing the degree.

To reinforce the conceptual understanding of such concepts and complement the teaching in an ERL scenario, a series of nine didactic videos was created in *Sígueme la Corriente*, entirely substituting any intervention from the professor about these topics. Thus, the second research objective (RO2) was to analyze if the use of dissemination videos optimized for educational purposes was able to mitigate some of the impacts of ERL on education quality perception, academic performance, motivation, and interest in the subject.

Therefore, the specific research questions contributing to the RO2 are:

- **RO2.Q1:** Did ERL produce differences in education quality perception and academic performance?
- **RO2.Q2:** Did didactic videos contribute to mitigating the impact of ERL from the students' perspective?
- **RO2.Q3:** Did didactic videos contribute to boost motivation and interest in the subject?

The positive results obtained through this experience motivated the creation of a specific line of educational videos in the channel. These new contents benefit from the characteristics of dissemination style and optimize the metrics for adequate integration in formal education: e.g., using more animations, providing more detailed information, and reinforcing the explanations of the practical applications of the topics, and their connections with other relevant concepts.

As reflected in Figure 12, this RO is aligned with the following research lines: Metrics to optimize the educational value of videos, the potential of dissemination resources in education, the use of videos in ERL scenarios, and the use of videos to foster interest in STEM disciplines.

3.2.3 RO3: Comparative analysis of the educational and dissemination use of a YouTube channel

After introducing of dissemination contents optimized explicitly for educational use in *Sígueme la Corriente*, there was a remarkable change in the growth tendency of the channel. Figure 13 shows the evolution of the daily and aggregate views of the channel during its whole lifetime (six years from January 2017 to December 2022). Such an effect on educational videos is represented in the green dotted trendline for stage 3.

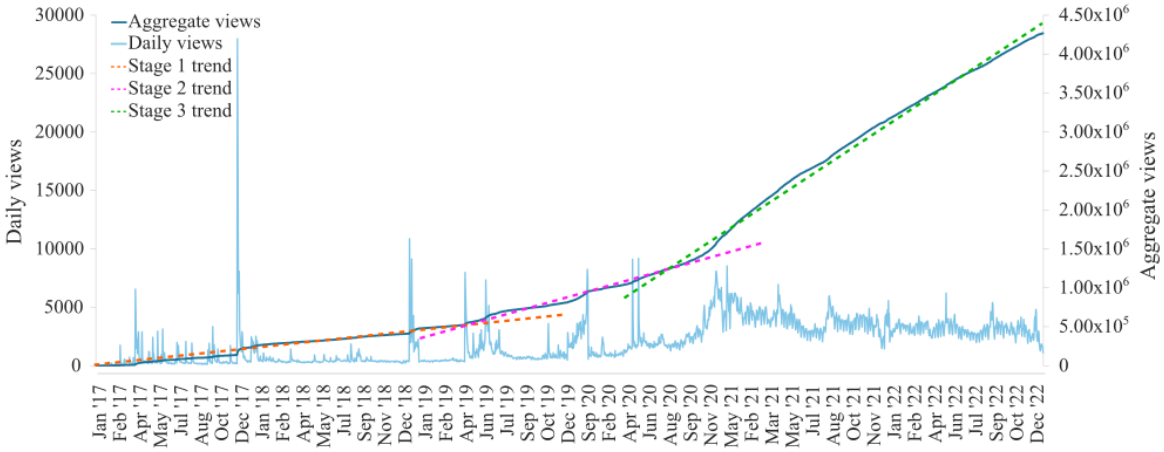


Figure 13. Daily and aggregate views during the whole channel's life, showing in dotted lines its three definitory stages: presentation (orange), consolidation (pink), and reconceptualization (green).

In case such trend change was correlated with the publication of educational content, this might unveil the potential benefits for a STEM YouTube channel to start optimizing its content for complementary educational use. Therefore, the research objective number 3 (RO3) pursued in this doctoral thesis aims to provide such analysis, focusing on how a YouTube channel might evolve to satisfy the dual needs from the dissemination and education perspective in STEM disciplines, as well as the comparative performance of both types of contents.

Consequently, this objective mainly focuses on deeply understanding the comparative performance of dissemination videos versus educational videos in the context of a STEM YouTube channel, and the factors influencing it.

On the one hand, RO3 aims to evaluate to which extent the channel is being used for educational or dissemination purposes to confirm if the educational use (initially assumed as secondary use of the channel) might have become its

predominant use due to the new education-focused strategy. On the other hand, the detailed owner's information for this channel is considered valuable in further providing data-based evidence about video length relevance for educational and entertainment content, based on the retention rate. Analyzing this parameter and other influencing metrics for video popularity, this study intends to provide further empirical evidence that complements the previous analyses on the channel's audience perception of the foremost parameters to define a good quality video for education.

Therefore, the specific research questions contributing to the RO3 are:

- **RO3.Q1:** Is the educational use of a STEM YouTube channel higher than the entertainment use?
- **RO3.Q2:** Is video length determinant for video performance in both education and dissemination purposes?

As reflected in Figure 12, this RO is aligned with the following research lines: Metrics to optimize the educational value of videos and the potential of dissemination resources in education.

3.3 Materials and Methods

The overall research design in this doctoral thesis is a mixed methods sequential explanatory design. It is intended to complement quantitative analyses based on several data collection instruments with qualitative data obtained through structured and semi-structured interviews and open participation. The following subsections will further introduce the specific research design followed in each RO.

3.3.1 Research design for RO1

The RO1 of this doctoral thesis intends to evaluate the perception of the educational use of a YouTube STEM dissemination channel. Such objective has been addressed through a pre-experimental design, which is adequate to measure personal perceptions about a specific topic or curricular innovations (Cohen et al., 2002; Jorrín Abellán & Fontana Abad, 2021). Such a non-experimental approach is implementing a survey-based descriptive design, complemented afterward by a qualitative analysis based on open contributions.

The objective of both designs is to evaluate the opinion that the users of *Sígueme la Corriente* channel had on its value and adequacy to be used as an educational tool before videos designed explicitly for education were published. The questionnaire used has been specifically designed as part of this doctoral thesis, and it is presented in the subsection 3.3.2.

First, during the exploratory analysis on the adequacy of *Sígueme la Corriente* channel for educational use, the population considered was the total number of the channel's subscribers when data was collected, quantified as 69,829 users. The sample was obtained through voluntary participation after the questionnaire was provided to the channel's users through video announcements from July 14th until July 31st, 2020. A total number of 912 participants was achieved.

According to the Cochran equation with finite population correction (1) (Cochran, 1963), the minimum sample size (n) needed to represent the population (N) of 69,829 users with a margin of error (ε) of 5% and a confidence value of 95% (1.96 Z score) would be 383 individuals. Therefore, the reached sample of 912 users exceeds the minimum representative sample, and the resulting error margin is 3.2%.

$$n = \frac{\frac{Z^2 \cdot p(1-p)}{\varepsilon^2}}{1 + \frac{Z^2 \cdot p(1-p)}{\varepsilon^2 N}} \quad (1)$$

3.3.2 Research design for RO2

The RO2 of this doctoral thesis intends to evaluate the impact of specifically designed educational videos in real classroom interventions during ERL.

In this case, the mixed methods sequential explanatory design was composed of a quasi-experimental post-test design with the control group for the quantitative approach, intended to assess the variations of students' perception of education quality during the experiment, as well as the variation in academic performance. Afterward, a case study qualitative approach was implemented based on a structured interview with voluntary students, which allowed to deeply assess how the proposed videos may have affected students' motivation and engagement.

As explained in the subsection 3.2.2, this RO was developed using as a case study the situation of the BSc. Degree in Electrical Engineering from the School

of Industrial, Aerospace, and Audiovisual Engineering of Terrassa at *Universitat Politècnica de Catalunya*. The challenge was to provide a video-aided strategy with dissemination videos from *Sígueme la Corriente* that were explicitly designed to optimize the features that make them adequate for educational use. Those videos would be integrated into real classroom interventions to alleviate bottlenecks generated by the disparity in the understanding of basic concepts for the electrical engineering branch courses.

First, it was crucial to detect the thematic areas requiring additional support in the Electrical Engineering BSc. For this purpose, concept maps have been used as a helping tool to highlight the central relations among key ideas in different subjects. Therefore, such visual schemes contribute to identify key topics where the benefits of didactic videos could be optimal to reinforce not only a subject's topics of interest but also their relationship with other subjects of the degree (Bodzin et al., 2010; Novak et al., 1984).

In this case, the critical concepts detected for the Electrical Engineering BSc. are electromagnetism and 3-phase circuits, as represented in Figure 14. Such figure shows a concept map including all the courses composing the degree and highlighting the presence of both key concepts, which act as a bottleneck for up to 32.2% of the degree. Moreover, Figure 15 and Figure 16 respectively show how electromagnetism and 3-phase circuits are related to previous concepts in the degree, and also to concepts to which they act as fundamental knowledge. For more information on how concept maps were developed and how they were implemented, please refer to Appendix I of Paper 2).

The use of these concept maps has allowed to detect such key areas that a video-aided reinforcement would benefit. Moreover, the adequate moment to implement such reinforcement was established in the course "Electrical Machines I" (60 hours), as it is the first electrical engineering specialization course. Therefore, a series of 9 videos was developed in *Sígueme la Corriente* as part of this study, bringing the benefits of video-based learning to understanding electromagnetism and 3-phase circuits. Both topics are composed of complex physics and mathematics abstract concepts in which animations and visual explanations play an essential role. These videos were created considering specific criteria to optimize their educational value, as exposed in the section 3.1. Then, during the course the videos were distributed to students through Moodle and made available through two playlists of the channel: Electromagnetism (Lijo, 2020c) and 3-Phase Circuits (Lijo, 2020b).

This study covered three academic years (from 2019 to 2022), extending through pre-ERL, ERL and post-ERL scenarios. A total sample of 157 students has been considered. On the one hand, a control group was established with

students from pre-ERL scenario who had not been exposed to any eLearning or video-based methodology and only followed a strictly traditional pedagogical approach. On the other hand, the experimental groups completed the course following a distance learning approach with complementary video support, starting with ERL during the COVID-19 pandemic and continuing with a more normalized distance learning situation through post-ERL scenario.

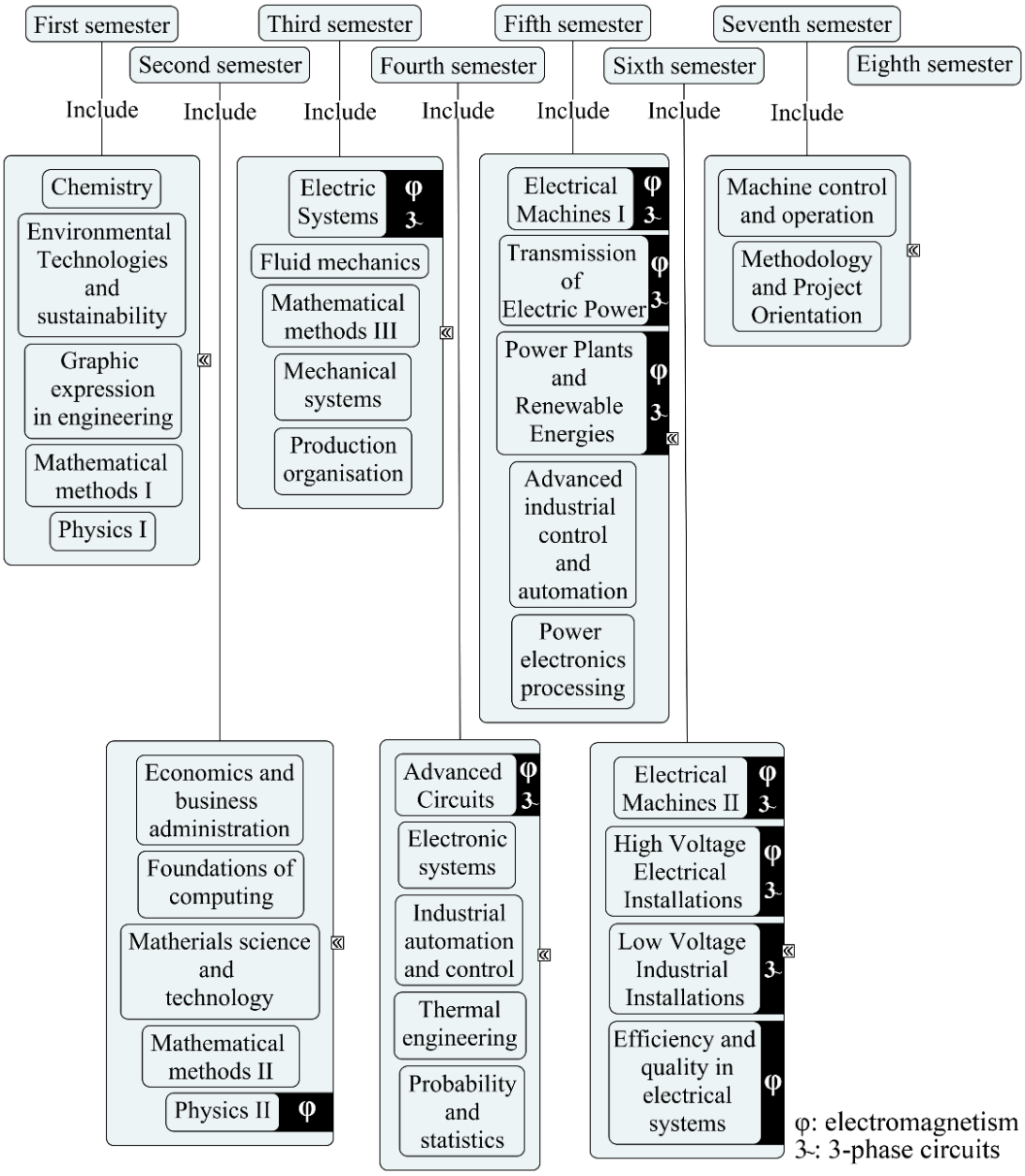


Figure 14. Concept map of compulsory subjects in BSc in Electrical Engineering, marking those related to electromagnetism (φ symbol) and 3-phase circuits (3~ symbol).

As instruments to measure the impact of the intervention, the Students' Evaluation of Educational Quality (SEEQ) validated questionnaire was

implemented, and the information came from grades reports for the three academic years contemplated. Moreover, a structured interview was developed to acquire qualitative information. All these data collection instruments are adequately introduced in the subsection 3.3.2.

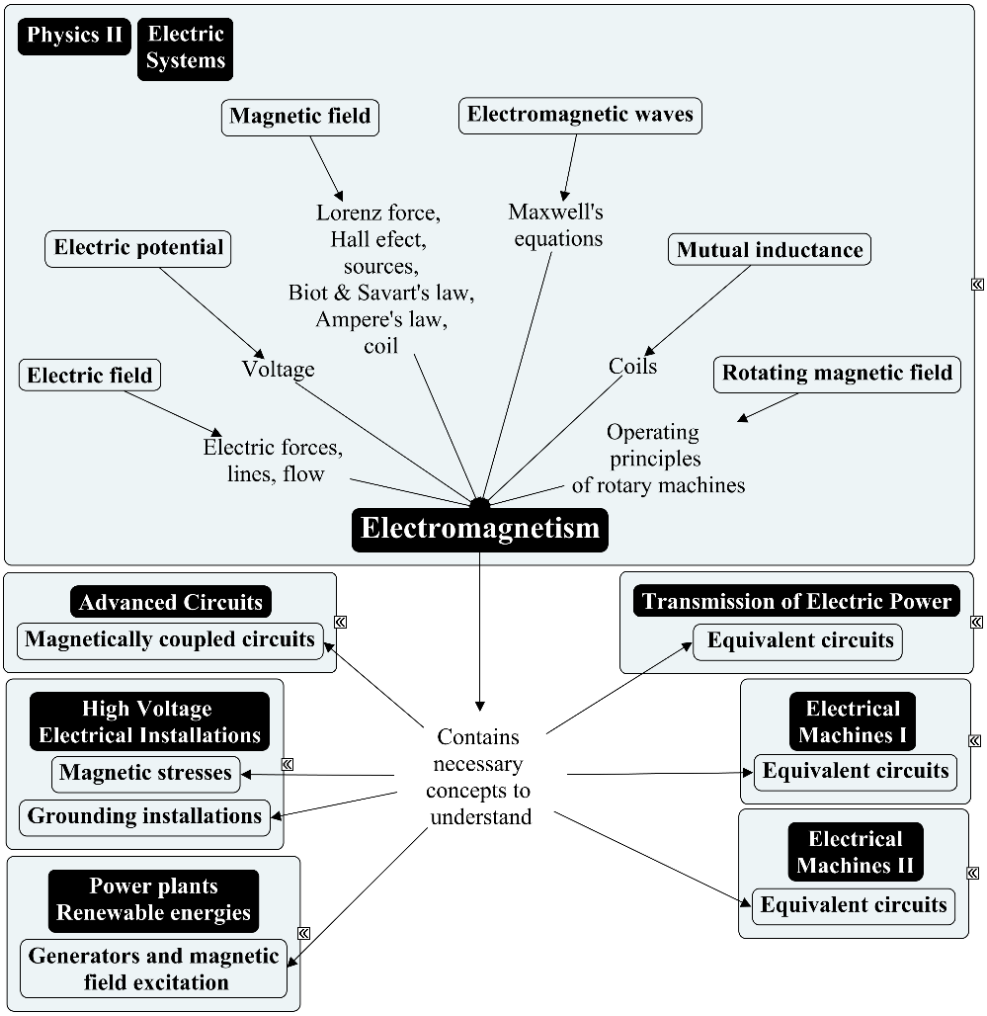


Figure 15. Concept map detailing both the concepts preceding electromagnetism and the concepts to which electromagnetism understanding is needed.

3.3.1 Research design for RO3

The RO3 of this doctoral thesis intends to comparatively analyze the educational and dissemination use of a YouTube channel. This objective was defined after the reconceptualization phase of the channel to assess the use of the educational content of the channel versus its dissemination contents. An

observational and correlational non-experimental research design has been followed for this research objective.

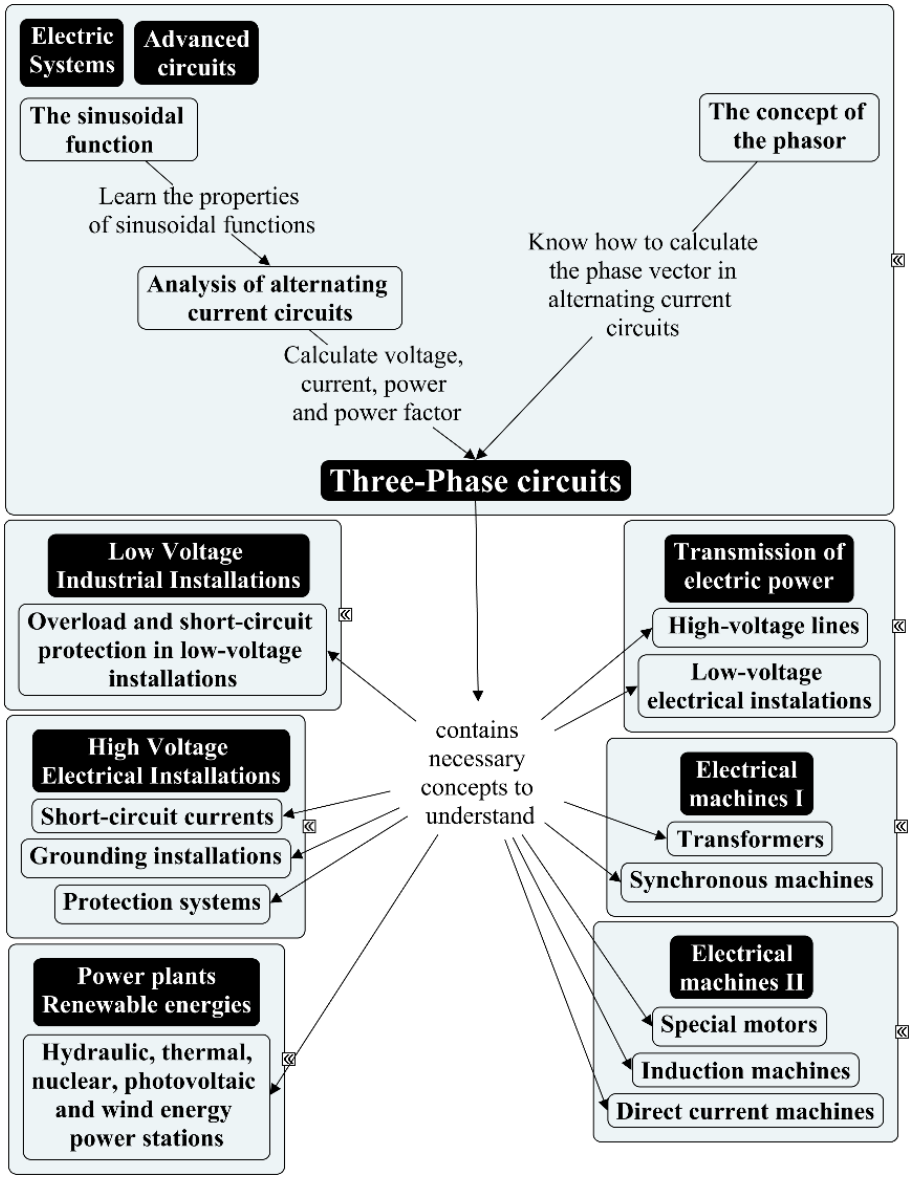


Figure 16. Concept map detailing both the concepts preceding 3-phase circuits and the concepts to which 3-phase circuits understanding is needed.

The analyzed information covers the historical evolution of the most relevant parameters of the channel during six years. Such parameters are grouped into those referring to reach and awareness (i.e., impressions, views and subscribers), use (average view duration), and interaction (comments, shares, likes, and dislikes). Moreover, video length is considered a pre-defined parameter that does not depend on the channel's use, as it is also the case for video categories set up by intentionality. And finally, contextual variables are considered, such

as the demographic information of users (gender, age, country, and city) and the device type used when consuming the channel's contents. All the previous information is collected from YouTube Analytics, accessible through *Sígueme la Corriente*'s YouTube Studio for owners (Google LLC, 2022). This tool is further explained in the subsection 3.3.2.

The sample for this study consisted of 147 videos, representing the total number of videos published in the channel under the three pre-established categories due to intentionality: educational, dissemination and others (please, refer to the Introduction for more information). All the videos considered in this study were originally created by *Sígueme la Corriente* and published in the channel, excluding any content from third parties that might be present in specific playlists (e.g., interviews in TV programs or collaborations in other channels). The information collected for all videos has allowed us to obtain a contextual understanding of the main metrics evolution through time. It represents the consumption behavior of the 146,772 subscribers and the 4,268,071 views gathered when the research took place (considering the period from January 1st, 2017, to December 31st, 2022).

3.3.2 Instruments and Data Collection

This subsection presents the different instruments and data collection methods used in the doctoral thesis. These sources include a survey designed as part of the research, other validated questionnaires from literature, grades reports, interviews and open participation, and YouTube Studio for owners.

Designed survey

A survey has been designed to evaluate *Sígueme la Corriente* users' perception of its value and adequacy to be integrated as educational resource. This survey was mainly used as a data collection instrument for RO1.

Table 1 shows the designed questionnaire, consisting of 18 questions grouped in three main categories: assessment of the channel use preferences, assessment on the channel's contents and format adequacy, and general perception about video-aided education. It is a 5-point Likert scale questionnaire, with descriptors adopted as per the general consensus in the literature about what aspects define an adequate educational video (see the section 1.2 for more information about this topic).

Table 1. Questionnaire for exploratory analysis of the channel's users' perceptions about its adequacy as an educational resource.

ID	Questions
Q1	I watch the channel's videos the same week they are published.
Q2	I watch old channel videos.
Q3	I use the channel for educative purposes.
Q4	I use the channel for entertainment purposes.
Q5	I use the channel to stay updated on news in the sector.
Q6	The selection of topics and content matches my interests.
Q7	The presenter's explanations are attractive and interesting.
Q8	The rhythm of videos is adequate for concept comprehension.
Q9	The technical level is adequate (I can follow the concepts and I also learn new things).
Q10	The channel's contents are rigorous.
Q11	Its contents help me understand topics I'm interested in.
Q12	The video's contents are up to date.
Q13	The video's duration is adequate.
Q14	Audiovisual resources used (images and music) are helpful to understand concepts.
Q15	Didactic videos could help to enhance education quality.
Q16	Classrooms are well equipped for the projection of didactic videos.
Q17	Professors should be provided with competences for the creation of own didactic videos.
Q18	Didactic videos can substitute assistance-based education.

After data was collected, the reliability of this instrument was validated through Cronbach's alpha method, obtaining a coefficient of 0.76. This score is considered adequate according to the common standards for exploratory research driven at early stages of a research line. In these cases, the reliability values should be equal or higher than 0.6 (Huh et al., 2006; Nunnally, 1967).

After the instruments' validation, Bartlett's test of sphericity and Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy were studied to verify the possibility of performing an exploratory factorial analysis. Results showed the following values: χ^2 (153) = 2315.3 ($p<0.001$); KMO = 0.850. This confirms the instruments' adequacy for a factorial analysis, which helped to identify five factors that explain at least 50% of the variance.

Such factors are presented hereafter sorted by the research questions contributing to RO1:

- **Assessment of the channel use preferences:**
  - Channel use for non-educative purposes (Q4, Q5, Q10, Q12).
  - Fan phenomenon (immediacy) (Q1).
- **Assessment on the channel's contents and format adequacy:**
  - Content adequacy to solve problems or satisfy topics of interest (Q2, Q3, Q6, Q9, Q11).

  - Audiovisual format and communicative style adequacy (Q7, Q8, Q13, Q14, Q15).

- **General perception on video-aided education** (Q16, Q17, Q18).

Survey from Literature

To evaluate the perception of the educational quality in real classroom interventions, the Students' Evaluations of Educational Quality (SEEQ) survey has been used (Coffey & Gibbs, 2001; Marsh, 1982). As shown in Table 2, it is composed of thirty-two 5-point Likert scaled questions organized in nine factors: F1 Learning, F2 Enthusiasm, F3 Organization, F4 Group Interaction, F5 Individual rapport, F6 Breadth, F7 Exams, F8 Assignments, and F9 Overall.

This questionnaire is a widely used instrument for student feedback due to its well-developed factor structure, high reliability, and reasonable validity (Coffey & Gibbs, 2001). It has been a central instrument in developing the research associated with RO2.

Grades reports

Grades reports have also been used in RO2 as a source of information to evaluate the impact of the proposed video-aided pedagogical strategy on academic performance, also considering the effects of ERL. The evaluation has been based on a direct comparison between the experimental and control groups.

Interviews and open participations

As part of the Mixed Methods research design, qualitative information was also compiled to allow a more profound analysis that provided complementary meaning to the quantitative information extracted through the research. Both open participation and a structured interview have been used as methods to compile such qualitative insights.

Table 2. Students' Evaluation of Educational Quality (SEEQ) survey, distinguishing between factors: F1 Learning, F2 Enthusiasm, F3 Organization, F4 Group interaction, F5 Individual rapport, F6 Breadth, F7 Exams, F8 Assignments, and F9 Overall.

Factors	Questions
F1	1 I have found the subject intellectually challenging and stimulating.
	2 I have learned something which I consider valuable.
	3 My interest in the theme has increased because of this subject.
	4 I have learned and understood the contents of this course.
F2	5 The professor was enthusiastic about teaching the subject.
	6 The professor was dynamic and energetic in conducting the subject.
	7 The professor enhanced presentations with the use of humor.
	8 Professor's style of presentation held my interest during class.
F3	9 Professor's explanations were clear.
	10 Subject materials were well prepared and carefully explained.
	11 Proposed objectives agreed with those actually taught so I knew where the subject was going.
	12 The professor gave lectures that facilitated taking notes.
F4	13 Students were encouraged to participate in class discussions.
	14 Students were invited to share their ideas and knowledge.
	15 Students were encouraged to ask questions and were given meaningful answers.
	16 Students were encouraged to express their own ideas.
F5	17 The professor was friendly towards individual students.
	18 The professor made students feel welcome in seeking help/advice in or outside of class.
	19 The professor had a genuine interest in individual students.
	20 The professor was adequately accessible to students during office hours of after class.
F6	21 The professor contrasted the implications of various theories.
	22 The professor presented the background or origin of ideas/concepts in or outside of class.
	23 The professor presented points of view other than his/her own when appropriate.
	24 The professor adequately discussed current developments in the field.
F7	25 Feedback on examinations/graded materials was valuable.
	26 Methods of evaluating student work were fair and appropriate.
	27 Examinations/graded materials tested course content as emphasized by the instructor
F8	28 Required readings/texts were valuable.
	29 Reading, homework, laboratories contributed to appreciation and understanding of subject.
F9	30 Compared with other subjects I have had at the university, I would say this one is:
	31 Compared with other professors I have had at the university, I would say this one is:
	32 As an overall rating, I would say the professor is:

On the one hand, open participations were mainly used to support RO1. In that case, the overall appreciation of the channel's use was compiled, asking the audience to mainly focus on the quality, interest, and utility of the videos published in the channel for didactic use.

On the other hand, a structured interview was developed to support RO2, aiming to evaluate more deeply how the proposed videos may have affected students' motivation and engagement throughout the course where they had been integrated, despite the identified adverse effects of ERL. This qualitative assessment aims to better understand, and cross-check, previous results obtained through the SEEQ survey and the academic performance data

obtained from grades reports. The interview's structure has been based on the following tensions deducted from the research questions of RO2:

- Distance education impact on academic performance.
- Quantity of videos watched in the video-based activity (1-9).
- Type of use of the videos (satisfying curiosity, exam preparation, etc.).
- Impact of videos on motivation and interest in the subject.
- Relevance of the content creator's identity (professor vs. professional in the field).
- Implications of proposed videos as teaching complement.

YouTube Studio

When accessing the advanced mode of the Analytics section of YouTube Studio for owners, a variety of parameters are presented that are designed to assist in assessing a channel's performance and usage. These metrics are categorized into several concepts as outlined below:

- **Overview:** watch time (hours), views, average view duration, average percentage viewed, subscribers, videos added, and videos published.
- **Reach:** impressions, impressions click-through rate, shown in feed, viewed (vs. swiped away), unique viewers, average views per viewer, new viewers, and returning viewers.
- **Interactions:** subscribers gained, subscribers lost, likes, dislikes, likes (vs. dislikes), shares, and comments added.
- **Playlists:** playlist watch time (hours), views from playlist, playlist average view duration, playlist average percentage viewed, playlist starts, playlist exits, playlist exit rate, average time in playlist, views per playlist start, and playlist saves.

RO3 primarily focuses on selecting the most relevant parameters for the intended scope among all the available metrics. These are grouped into reach and awareness (i.e., impressions, views, and subscribers), usage (average view duration), and interaction (comments, shares, likes, and dislikes). Video length is also considered a pre-defined parameter independent of the channel's usage, like the video categories set up by intentionality (dissemination, education, or others). Lastly, contextual variables like demographic information of users

(gender, age, countries, and cities) or the device type used to consume the channel's contents are considered.

3.3.3 Data analysis and tools

The methodology for the data analysis has been meticulously designed and executed according to the nature of the variables obtained in data collection and also aligned with the different research objectives.

First, for the statistical analyses used in the quantitative approach, the following specialized software has been employed: SPSS (IBM, 2022) and Jamovi (Jamovi, 2023; R Core Team, 2021). In all cases, a confidence level of 95% has been considered. After performing Shapiro-Wilk normality test confirmations, different parametric and non-parametric data have been selected respectively for the normal and non-normal distributions of collected data.

Besides descriptive statistics used to analyze and represent relevant explanatory information, different statistical tests have also been employed. The Mann-Whitney *U* test has been utilized to compare independent samples of non-normal data, with the aim of identifying significant differences between studied groups when considering continuous variables. Moreover, χ^2 tests of association have been employed to evaluate the correlations between discrete quantitative variables. Lastly, for identifying significant relations among relevant metrics for video performance, Spearman's correlation analyses have been used for non-parametrical distribution of variables.

For the qualitative analysis, ATLAS.ti software has been used (ATLAS.ti, 2022). The participations have been coded following a deductive process after initial exploratory evaluations. Given the nature of the sample considered in both participation and structured interviews, the information was collected in Spanish, and equivalent English terms have been considered for codes, aligning them with the concepts commonly used in literature. Cooccurrence analyses have been performed to detect relevant relations among codes, and Sankey diagrams have been used for their graphic representation.

Complementary to the analyses above, demographic analysis and map representations have been conducted using Quantum GIS software (QGIS, 2022). Furthermore, concept maps have been created using CMapTools (IHMC, 2022), to aid in visualizing and understanding complex concepts and the relationships among them.

3.3.4 Data availability

Aiming to promote an open research culture, and to ensure replicability, the datasets considered in this research have been shared in different open access repositories. They are accessible through the following links:

- **Dataset:** Dataset for *Sigueme la Corriente* audience perception on its educational value (Lijo, 2021).
  - Repository: IEEE Dataport.
  - Publisher: Institute of Electrical and Electronics Engineers (IEEE).
  - DOI: https://dx.doi.org/10.21227/t7w2-bh15
- **Dataset:** Didactic Videos Integration in "Electrical Machines I" subject (BSc in Electrical Engineering from ESEIAAT - UPC) (Lijo, Quevedo, et al., 2022b).
  - Repository: IEEE Dataport.
  - Publisher: Institute of Electrical and Electronics Engineers (IEEE).
  - DOI: https://dx.doi.org/10.21227/x5pn-m995
- **Dataset:** Dataset for Sígueme la Corriente STEM YouTube Channel (Lijo, 2023).
  - Repository: Mendeley Data.
  - Publisher: Elsevier.
  - DOI: https://dx.doi.org/10.17632/gb88yvcv3m.1

4

CONTRIBUTIONS

BUILDING UP ON THE RESEARCH GAPS

4. Contributions:
Building up on the research gaps

This section addresses and builds upon the identified research gaps through a series of targeted research objectives already presented in previous sections. These objectives have been designed to enhance our understanding and utilization of STEM dissemination audiovisual resources in the educational context. First the doctoral thesis timeline and publications are presented, aiming to clearly describe a chronological overview of the research strategy and its dissemination. Then, the contribution of this doctoral thesis to each one of the research objectives is presented in three subsections. Through the executed research strategy, this thesis seeks to make significant contributions to digital education, educational technology, and STEM education and dissemination.

4.1 Timeline

This timeline section serves the purpose of providing a chronological overview of the various publications that have been instrumental in shaping and enriching the research journey presented through this document. To provide a visual representation of this timescale, Figure 17 presents a schematic view of all the publications, plotted against time, and spread through the primary research lines considered. It offers a clear and concise view of the academic progression throughout the development period of this doctoral thesis. The initial research activity preceding the start of this thesis has been omitted from the scheme.

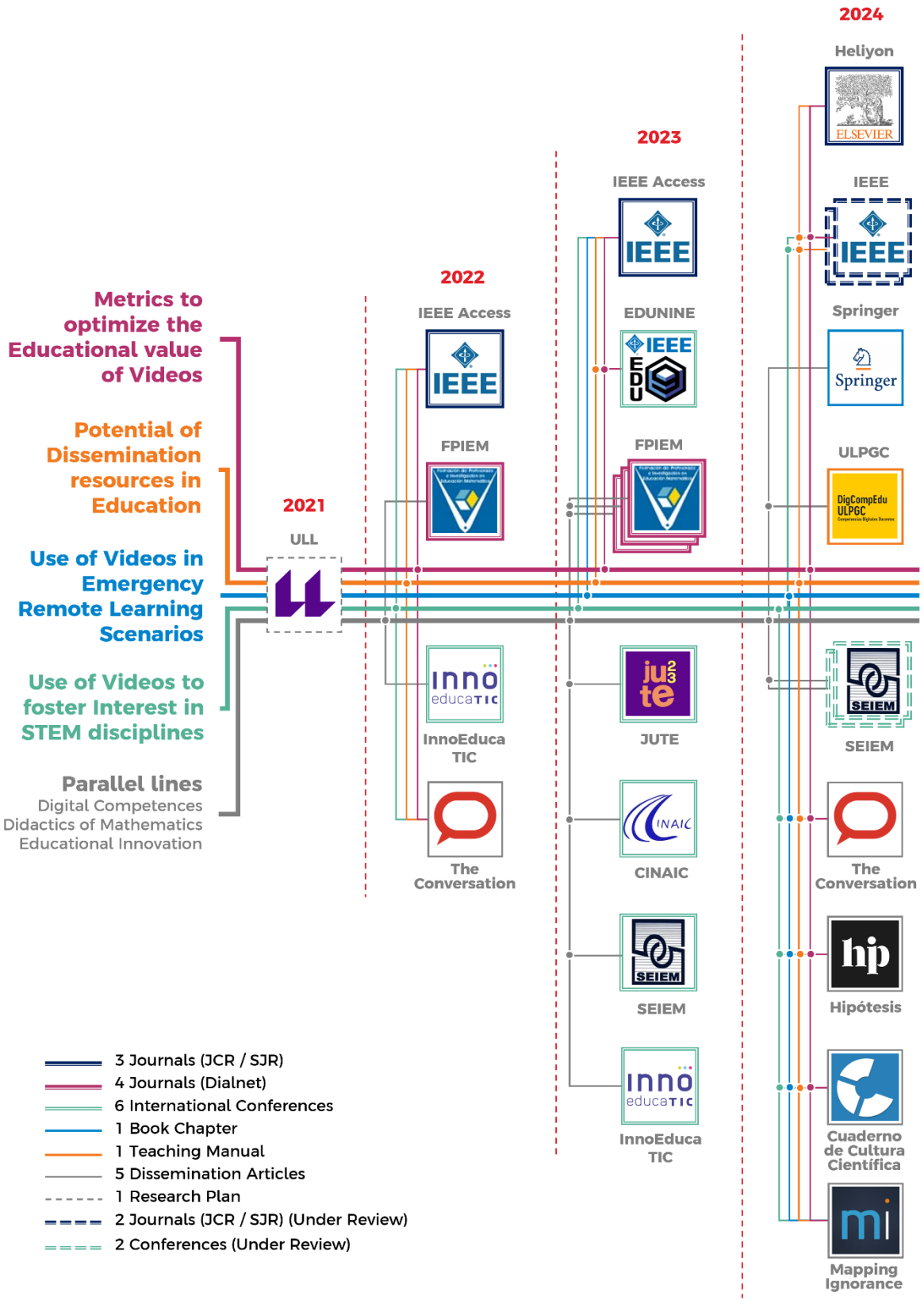


Figure 17. Timeline of the research lines involved in this doctoral thesis.

The timeline begins with the foundational works that set the stage for the doctoral thesis, encompassing educational innovation articles and book chapters, as well as a teaching manual on MOOC creation framed under the scope of developing the digital competence of academics and educators.

The heart of this timeline, and indeed the thesis itself, is the compendium of articles that dive deeper into using dissemination videos to enhance STEM formal education, with YouTube serving as a key source of such material. Three journal articles and an international conference article build up the compendium presented in this doctoral thesis.

Alongside these core publications, parallel research lines have also allowed us to explore complementary aspects to this thesis focus, such as the digital competence of educators, educational innovation mechanisms and resources, and didactics of mathematics.

Lastly, this timeline acknowledges the importance of making research accessible to the public, featuring articles published in dissemination sites and press. This has allowed sharing the results of this research to make it available to society through newspapers, online specialized sites, and magazines.

4.1.1 Background for this doctoral thesis

As exposed through the literature review, the integration of multimedia resources in STEM education has become increasingly significant. Among these resources, dissemination audiovisual materials might be promising in this field as available resources with educational potential. These dynamic tools offer the potential to transform learning experiences, bridging the gap between complex subject matters and diverse learners.

This doctoral thesis has been shaped after more than a decade of dedication to scientific communication, merging passion and expertise. The combination of academic background in engineering with experience in the coordination and design of online training plans and massive online open courses, establishes a starting point for the definition of a doctoral thesis studying the implications of dissemination videos for technology-enhanced STEM learning. Therefore, the central question of this doctoral thesis revolves around how audiovisual dissemination resources can enhance STEM education.

Moreover, this path builds on the foundations of initial educational innovation contributions exploring the use of videos, humor, and music as tools for educational enhancement. The works published before the beginning of this doctoral thesis are presented hereafter:

- **International Conference Article:** Impact of using audio-visual material on didactics of mathematics in primary school (Quevedo Gutiérrez et al., 2017). **Published in 2017 at:** IV Jornadas Iberoamericanas de Innovación Educativa en el Ámbito de las TIC y las TAC (InnoEducaTIC 2017).
- **International Conference Article:** Stimulating STEAM learning through the use of humor (Lijo et al., 2017). **Published in 2017 at:** IV Jornadas Iberoamericanas de Innovación Educativa en el Ámbito de las TIC y las TAC (InnoEducaTIC 2017).
- **Book Chapter (SPI Q1):** *Herramientas audiovisuales para la elaboración de recursos didácticos en disciplinas STEAM* [Audiovisual tools for the elaboration of didactic resources in STEAM disciplines] (Lijo et al., 2018). **Published in 2018 at:** Experiencias pedagógicas e innovación educativa: aportaciones desde la praxis docente e investigadora (Octaedro Editorial).
- **Book Chapter (SPI Q1):** *Potenciales usos de la música como herramienta vehicular para la enseñanza de disciplinas STEAM* [Potential uses of music as a vehicular tool for teaching STEAM disciplines]. Un caso práctico (López López et al., 2020). **Published in 2020 at:** Claves para la innovación pedagógica ante los nuevos retos: respuestas en la vanguardia de la práctica educativa (Octaedro Editorial).
- **Book Chapter:** *El humor y el audiovisual como herramientas didácticas en disciplinas STEAM* [Humor and audiovisuals as didactic tools in STEAM disciplines] (Lijo et al., 2020). **Published in 2020 at:** Tendencias Metodológicas en Innovación Educativa (Servicio de Publicaciones y Difusión Científica de la Universidad de Las Palmas de Gran Canaria (ULPGC)).
- **Teaching Manual:** Massive Online Open Courses (MOOC): *una guía práctica para docentes* [Massive Online Open Courses (MOOC): a practical guide for teachers] (Lijo, 2020a). **Published in 2020 by:** Servicio de Publicaciones y Difusión Científica de la Universidad de Las Palmas de Gran Canaria (ULPGC).

4.1.2 Compendium of articles

After the initial definition of the research plan backing up this doctoral thesis, the research activity began with an exploratory analysis of the perceived educational value in the dissemination videos of a successful Spanish STEM YouTube channel. This exploratory analysis was followed by the definition of experimental research that counted with the creation of a specific series of videos for educational purposes and a classroom intervention lasting three

academic courses. And finally, the performance of dissemination and educational content on YouTube, as well as the consumption behavior in both cases, was comparatively evaluated through an extension period of six years.

These research activities were consolidated in three academic articles published in prestigious international journals, and in a communication for one of the leading conferences in the field of educational technology and engineering education. The publications composing the compendium of articles for this doctoral thesis are presented hereafter:

- **Journal Article (JCR Q2 – SJR Q1):** Assessing Users' Perception on the Current and Potential Educational Value of an Electrical Engineering YouTube Channel (Lijo, Quevedo, et al., 2022a). **Published in 2022 at:** IEEE Access - Education Society Section (IEEE).
- **Journal Article (JCR Q2 – SJR Q1):** Impact of Electrical Engineering Didactic Videos During Emergency Remote Learning (Lijo, Quevedo, Castro, et al., 2023). **Published in 2023 at:** IEEE Access - Education Society Section (IEEE).
- **Journal Article (JCR Q2 – SJR Q1):** Comparing educational and dissemination videos in a STEM YouTube channel: A six-year data analysis (Lijo et al., 2024). **Published in 2024 at:** Heliyon - Education Section (Cell Press & Elsevier).
- **International Conference Article (Scopus):** Qualitative Assessment of the Educational Use of an Electrical Engineering YouTube Channel (Lijo, Quevedo, & Castro, 2023). **Published in 2023 at:** 2023 IEEE World Engineering Education Conference (EDUNINE).

4.1.3 Parallel Research Lines

This section presents the parallel research lines that have been pursued alongside the primary focus of this doctoral thesis. The first line of inquiry extends the core thesis research, exploring the dual use of videos for STEM dissemination and education. This work seeks to harness the power of visual media as a tool for both sharing scientific knowledge and enhancing pedagogical methods in STEM fields. The second research line investigates the development of digital competences for educators, an essential facet in today's increasingly digital educational landscape. Lastly, the third research line focuses on the application of educational technology for the didactics of mathematics.

Dual use of videos for dissemination and education

Further constructing in the direction of the research developed within this doctoral thesis, additional publications have been developed to evaluate the dual use of didactic videos. In this case, the focus was on the approach taken by *Amautas* platform[21], merging the communicative style commonly associated with edutubers in structured courses with the characteristics typically found in Massive Online Open Courses. These studies have concluded in the following academic works:

- **Journal Article (SJR Q2):** The Dual Use of Didactic Videos in STEM Education and Dissemination: A Survey-Based Analysis. **Under Review:** IEEE Revista Iberoamericana de Tecnologías del Aprendizaje (IEEE).
- **International Conference Article:** *La plataforma Amautas como fuente de vídeos didácticos para la mejora de la educación y la divulgación STEAM* [The Amautas platform as a source of educational videos for the improvement of education and STEAM dissemination] (Lijo, Castro Sánchez, Quevedo, & Pérez, 2023). **Published in 2023 at:** XXX Jornadas Internacionales de Tecnología Educativa: 30 años de docencia e investigación en Tecnología Educativa: Balance y futuro.

Moreover, an additional research initiative has also been developed related to the use of videos and dissemination capabilities. It involves using videos and peer review to foster a regular study-homework routine in engineering students, as well as working on their critical thinking capabilities and increasing their motivation and interest in the discipline. It has been consolidated in the following academic work:

- **Journal Article (JCR Q2 – SJR Q1):** Learning Through Explanation: Producing and Peer-Reviewing Videos on Electric Circuits Problem Solving. **Under Review:** IEEE Transactions on Education (IEEE).

Digital competences for educators

Moreover, both literature and the works presented in this doctoral thesis have evidenced the need to enhance the digital competences of academics and educators. Such improvements will allow them to successfully consider educational technologies such as digital resources within their instructional designs. In this line, parallel activities have also been developed to evaluate

[21] https://amautas.com (Accessed 15/04/2024)

the digital competences of academics at the *Universidad de Las Palmas de Gran Canaria* and to create new training materials to foster such digital competences. These works have allowed the production of the following publications:

- **International Conference Article:** Analysis of the Digital Competence in the Teaching Staff of Universidad de Las Palmas de Gran Canaria (Lijo, Alonso, et al., 2022). **Published in 2022 at:** IX Jornadas Iberoamericanas de Innovación Educativa en el ámbito de las TIC y las TAC (InnoEducaTIC).
- **Teaching Manual:** *Diseño de Planes para la Formación Online* [Design of Online Training Plans] (Quevedo Gutiérrez & Lijo, 2024). **Under development to be published by:** Servicio de Publicaciones y Difusión Científica de la Universidad de Las Palmas de Gran Canaria (ULPGC).

However, in addition to these activities, the main parallel research line developed during this doctoral thesis has been focused on the role of educational technologies in the didactics of mathematics.

Educational technology for the didactics of mathematics

The leitmotiv of the research presented in this doctoral thesis builds up on the idea that STEM disciplines are composed by a high presence of abstract concepts that increases the cognitive load during their learning process. But, of all the disciplines composing the STEM concept, mathematics is by far the most abstract.

Therefore, special attention has been paid to mathematics as a parallel activity during this doctoral thesis. The main focus of this parallel research line has been the role of educational technologies enhancing mathematics understanding during the training of pre-service teachers. Computational thinking and educational robotics have played essential roles in the activities and interventions developed in this field.

From this activity, the following publications have been developed:

- **Journal Article (Dialnet):** *Proyecto de Centro de Pensamiento Computacional en Educación Primaria. Lecciones Aprendidas y Planificación Futura Partiendo del Real Decreto de Enseñanzas Mínimas de la LOMLOE* [Computational Thinking Center Project in Primary Education. Lessons Learned and Future Planning Based on the Real Decreto de Enseñanzas Mínimas de la LOMLOE] (Santana Coll et al., 2022). **Published in**

2022 at: Formación del Profesorado e Investigación en Educación Matemática.

- **Journal Article (Dialnet):** *Intervención de Pensamiento Computacional en Educación Infantil en el Marco de la Ordenación Curricular propuesta por la LOMLOE* [Computational Thinking Intervention in Early Childhood Education in the Framework of the Curricular Organization proposed by the LOMLOE] (Lijo, Díaz Díaz, Hernández Moreno, Zapatera Llinares, et al., 2023). **Published in 2023 at:** Formación del Profesorado e Investigación en Educación Matemática.
- **Journal Article (Dialnet):** *El Pensamiento computacional en el currículo de matemáticas de la enseñanza básica (LOMLOE) y la formación del profesorado… ¡una segunda oportunidad!* [Computational thinking in the elementary mathematics curriculum (LOMLOE) and teacher training... a second chance!] (Quevedo Sarmiento et al., 2023). **Published in 2023 at:** Formación del Profesorado e Investigación en Educación Matemática.
- **Journal Article (Dialnet):** *Análisis sobre la Predisposición frente a las Matemáticas del Estudiantado para Maestro en la Universidad de Las Palmas de Gran Canaria* [Analysis of the Predisposition towards Mathematics of the Pre-Service Teachers at the University of Las Palmas de Gran Canaria] (Lijo, Zapatera Llinares, Quevedo Gutiérrez, & Hernández Suárez, 2023). **Published in 2023 at:** Formación del Profesorado e Investigación en Educación Matemática.
- **International Conference Article:** *Percepción del estudiantado para maestro sobre la integración curricular del pensamiento computacional en su proceso formativo* [Perception of pre-service teachers on the curricular integration of computational thinking in their training process] (Lijo, Calcines, López-Puig, Zapatera Llinares, et al., 2023). **Published in 2023 at:** X Jornadas Iberoamericanas de Innovación Educativa en el ámbito de las TIC y las TAC (InnoEducaTIC).
- **International Conference Article:** *Invención de Situaciones Aditivas con Números Enteros* [Invention of Additive Situations with Integers] (Quevedo Gutiérrez et al., 2023). **Published in 2023 at:** Investigación en Educación Matemática XXVI (SEIEM).
- **International Conference Article:** Computational Thinking Intervention at the Transition Between Early-Childhood and Primary Education (Hernández Moreno et al., 2023). **Published in 2023 at:** VII Congreso Internacional sobre Aprendizaje, Innovación y Cooperación, CINAIC 2023.
- **Book Chapter (SPI Q1):** Computational thinking state in 3rd early childhood education and 1st primary education (Hernández Moreno et al., 2024).

Published in 2024 at: Innovation and Technologies for the Digital Transformation of Education – European and Latin American Perspectives (Springer).

- **International Conference Article:** *El obstáculo epistemológico del número como cantidad de magnitud en la enseñanza de los números enteros* [The epistemological obstacle of number as a quantity of magnitude in the teaching of integers]. **Under Review:** Investigación en Educación Matemática XXVII (SEIEM).
- **International Conference Article:** *Transferencias entre dimensiones abstracta, recta y contextual de situaciones aditivas con números enteros* [Transfers between abstract, line and contextual dimensions of additive situations with integers]. **Under Review:** Investigación en Educación Matemática XXVII (SEIEM).

4.1.4 Dissemination of research results

Sharing scientific results is not a mere formality, but a vital part of the scientific process. It encourages open science, enabling other researchers to reproduce, replicate, and build upon our work. Furthermore, it aids in fostering a scientific culture among society, enhancing their understanding and appreciation of science. The initial dissemination efforts for this doctoral thesis consist of original dissemination articles published on online platforms and magazines, as well as press coverage of the research results. By presenting these research findings in a comprehensive and accessible manner, we aim to stimulate dialogue, collaboration, and innovation, thereby pushing the boundaries of knowledge in the field of technology-enhanced education.

Dissemination articles

Two dissemination articles have been published in the international communication media The Conversation. It is a non-profit organization aiming to publish research results exclusively written by academics and researchers and published under the Creative Commons license.

The articles published focus on the potential value of YouTube dissemination videos for formal STEM education, and on how to select adequate videos for

such use appropriately. They are accessible through the information provided hereafter, and also an extract is presented in the chapter 10.

- **Dissemination Article:** *Conceptos abstractos que se aprenden mejor en vídeo* [Abstract concepts that are best learned on video][22]. **Published in 2022 at:** The Conversation.
- **Dissemination Article:** *Cómo seleccionar vídeos adecuados para uso educativo* [How to select adequate videos for educational use][23]. **Published in 2024 at:** The Conversation.

Moreover, three additional dissemination articles have already been accepted to present the overall outcomes of this doctoral thesis. They will be published in the following sites and magazines:

- **Mapping Ignorance**[24]: This is an online scientific communication site edited in English by the Chair of Scientific Culture of the *Universidad del País Vasco*, under the Project Campus of International Excellence – Euskampus. Their goal is to translate cutting-edge scientific research into an educated lay-person language and, therefore, contribute to map ignorance with new knowledge.
- **Cuaderno de Cultura Científica**[25]: This is an online scientific communication site also edited in Spanish by the Chair of Scientific Culture of the *Universidad del País Vasco*, under the Project Campus of International Excellence – Euskampus. Its activity aims to publish news about recent research, as well as general dissemination articles, opinion articles, and materials contributing to the construction of a scientific culture.
- **Hipótesis Magazine**[26]: This magazine is edited by the Scientific Culture and Innovation Unit of *Universidad de La Laguna* (UCC+i - *Cienci@ULL*), in cooperation with the *Consejería de Economía, Conocimiento y Empleo* at the Government of the Canary Islands, through the *Agencia Canaria de Investigación, Innovación y Sociedad de la Información*. It is a dissemination magazine designed to bring closer to society the research developed at the *University of La Laguna*.

Together, these dissemination efforts have contributed to the visibility of the research developed in this doctoral thesis. They have made such research methodology and results more accessible, and raised interest from the press.

[22] https://theconversation.com/conceptos-abstractos-que-se-aprenden-mejor-en-video-184078 (Accessed 15/04/2024).
[23] https://theconversation.com/como-seleccionar-videos-adecuados-para-uso-educativo-223132 (Accessed 15/04/2024).
[24] https://mappingignorance.org (Accessed 15/04/2024).
[25] https://culturacientifica.com (Accessed 15/04/2024).
[26] https://www.ull.es/portal/cienciaull/revistahipotesis (Accessed 15/04/2024).

Press coverage

As a result of the interest generated by the research developed in this doctoral thesis, as well as the works on its visibility through dissemination initiatives, several mass media have been interested in also contributing to spreading these results. They are of national and regional scopes, covered from the journalism perspective, and from an institutional perspective in the case of the universities involved in this research. The publications are accessible through the information provided hereafter, and also extracts are presented in the chapter 10.

- **National newspaper:** *Un estudio científico desestigmatiza YouTube en las aulas* [Scientific study destigmatizes YouTube in the classroom][27]. **Published in 2023 at:** La Razón (online and paper).
- **National newspaper:** *Un exalumno de la UPC triunfa en youtube divulgando ingeniería eléctrica* [A UPC alumnus triumphs on youtube through electrical engineering dissemination][28]. **Published in 2023 at:** La Vanguardia.
- **Regional newspaper:** *El 70% de los estudiantes utiliza YouTube para profundizar y mejorar en los estudios* [70% of students use YouTube to further and improve their studies][29]. **Published in 2023 at:** La Provincia (online and paper).
- **Regional newspaper:** *Un enginyer elèctric a qui seguir el corrent* [An electrical engineer to follow the current][30]. **Published in 2023 at:** Diari de Terrassa (online and paper).
- **Regional newspaper:** *"Sígueme la corriente": el canal de un exalumno de ESEIAAT triunfa en YouTube* ["Sígueme la Corriente": the channel of an ESEIAAT ex-student triumphs on YouTube][31]. **Published in 2023 at:** Món Terrassa.
- **Regional newspaper:** *"El youtuber de l'enginyeria elèctrica té ADN de Terrassa* [The youtuber of electrical engineering has DNA from Terrassa][32]. **Published in 2024 at:** Món Terrassa.

[27] https://www.larazon.es/ciencia/estudio-cientifico-desestigmatiza-youtube-aulas_20230405642d9aae1036390001b70648.html (Accessed 15/04/2024).
[28] Available in Appendix.
[29] https://www.laprovincia.es/sociedad/2023/03/03/educacion-youtube-estudiantes-tecnologias-84072665.html (Accessed 15/04/2024).
[30] https://www.diarideterrassa.com/terrassa/2023/03/31/un-enginyer-electric-a-qui-seguir-el-corrent (Accessed 15/04/2024).
[31] https://monterrassa.cat/es/economia-es/alumno-eseiaat-videos-youtube-326165 (Accessed 15/04/2024).
[32] https://monterrassa.cat/societat/video-youtuber-enginyeria-electrica-te-adn-de-terrassa-393152 (Accessed 15/04/2024).

- **Regional TV channel:** *El youtuber Rubén Lijó publica un nou vídeo gravat íntegrament a l'ESEIAAT* ["Youtuber Ruben Lijo publishes a new video recorded entirely at ESEIAAT][33]. **Published in 2024 at:** Terrassa Digital.
- **Institutional Communication:** *La ULPGC lidera un estudio sobre el uso de materiales audiovisuales como recurso pedagógico en las enseñanzas STEM* [ULPGC leads a study on the use of audiovisual materials as a teaching resource in STEM education][34]. **Published in 2022 at:** Universidad de Las Palmas de Gran Canaria.
- **Institutional Communication:** *La ULPGC lidera un estudio de integración de vídeos didácticos para mejorar la enseñanza de ingeniería* [ULPGC leads a study on the integration of didactic videos to improve engineering teaching][35]. **Published in 2023 at:** Universidad de Las Palmas de Gran Canaria.
- **Institutional Communication:** *Dos investigadores de la ULPGC ofrecen pautas en The Conversation para escoger vídeos adecuados con fines educativos* [Two ULPGC researchers offer guidelines in The Conversation for choosing appropriate videos for educational purposes][36]. **Published in 2024 at:** Universidad de Las Palmas de Gran Canaria.
- **Institutional Communication:** *ULL y ULPGC estudian el uso de materiales audiovisuales como recurso pedagógico en las enseñanzas STEM* [ULL and ULPGC study the use of audiovisual materials as a pedagogical resource in STEM education][37]. **Published in 2022 at:** Universidad de La Laguna.
- **Institutional Communication:** *Un 'alumni' de la ESEIAAT de la UPC triunfa en YouTube con 'Sígueme la Corriente', un canal divulgativo de Ingeniería Eléctrica* [An 'alumni' of the ESEIAAT of the UPC triumphs on YouTube with 'Sígueme la Corriente', an informative channel on Electrical Engineering][38]. **Published in 2023 at:** Universitat Politècnica de Catalunya.
- **Institutional Communication:** *Un exalumne de l'ESEIAAT de la UPC triomfa a YouTube amb 'Sígueme la corriente', un canal divulgatiu d'enginyeria elèctrica* [A former student of the ESEIAAT of the UPC triumphs on YouTube with 'Sígueme la corriente', an informative channel on electrical

[33] https://terrassadigital.cat/el-youtuber-ruben-lijo-publica-un-nou-video-gravat-integrament-a-leseiaat (Accessed 15/04/2024).
[34] https://www.ulpgc.es/noticia/2022/02/04/ulpgc-lidera-estudio-uso-materiales-audiovisuales-como-recurso-pedagogico (Accessed 15/04/2024).
[35] https://www.ulpgc.es/noticia/2023/03/30/ulpgc-lidera-estudio-integracion-videos-didacticos-mejorar-ensenanza-ingenieria (Accessed 15/04/2024).
[36] https://www.ulpgc.es/noticia/2024/03/07/dos-investigadores-ulpgc-ofrecen-pautas-conversation-escoger-videos-adecuados (Accessed 15/04/2024).
[37] https://www.ull.es/portal/noticias/2022/ull-ulpgc-estudian-audiovisuales-recurso-pedagogico-stem (Accessed 15/04/2024).
[38] https://www.upc.edu/es/sala-de-prensa/noticias/alumni-eseiaat-upc-triunfa-youtube-canal-sigueme-la-corriente-ingenieria-electrica (Accessed 15/04/2024).

engineering][39]. **Published in 2023 at:** Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa ESEIAAT – UPC.

- **Institutional Communication:** *Ruben Lijó, el 'youtuber' més seguit d'enginyeria elèctrica, publica un nou vídeo al canal 'Sígueme la corriente'", gravat íntegrament a l'ESEIAAT de la UPC* [Ruben Lijo, the most followed 'youtuber' in electrical engineering, publishes a new video on the channel 'Follow me the current'", recorded entirely at the ESEIAAT of UPC][40]. **Published in 2024 at:** Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa ESEIAAT – UPC.

4.2 Contributions to RO1

As introduced in the section 3.2, this doctoral thesis consists of three ROs that address four main research gaps. RO1 is focused on the perception of the educational use of a YouTube STEM dissemination channel. Figure 18 shows how RO1 is related to the evaluation of metrics to optimize the educational value of videos, to evaluate the potential of dissemination resources in education, and to detect if videos have an impact on fostering interest in STEM disciplines.

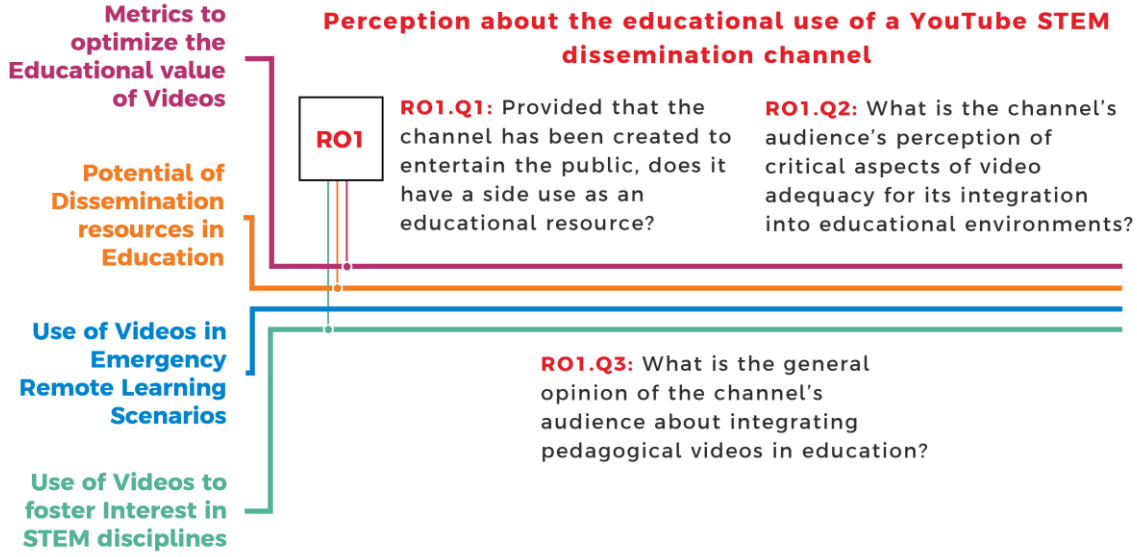


Figure 18. Research lines, Research Objective 1, and questions within it.

[39] https://eseiaat.upc.edu/ca/noticies/un-exalumne-de-eseiaat-de-la-upc-triomfa-a-youtube-amb-sigueme-la-corriente-un-canal-divulgatiu-enginyeria-electrica (Accessed 15/04/2024).
[40] https://eseiaat.upc.edu/ca/noticies/ruben-lijo-youtuber-mes-seguit-enginyeria-electrica-publica-un-nou-video-al-canal-sigueme-la-corriente-gravat-integrament-a-eseiaat-upc (Accessed 15/04/2024).

The insights contributing to RO1 belong to the initial research stage of this doctoral thesis, which was consolidated in the first article of the compendium (Lijo, Quevedo, et al., 2022a). Furthermore, additional qualitative information was analyzed and published in the IEEE World Engineering Education Conference (EDUNINE) (Lijo, Quevedo, & Castro, 2023). This case study was developed in 2020 and 2021 with the participation of 912 users of *Sígueme la Corriente* channel. The following subsections present the main contributions to the research questions building RO1.

RO1.Q1: Provided that the channel has been created to entertain the public, does it have a side use as an educational resource?

Despite its original intent as an entertainment and dissemination platform, *Sígueme la Corriente* YouTube channel has been widely utilized as an educational resource. This usage was observed even before the implementation of the specific pedagogical strategy that followed as part of this doctoral thesis. These findings support the initial hypothesis that an informal YouTube dissemination channel, created and developed primarily for entertainment, can also serve as an educational aid. Furthermore, the audience's perception of its educational value and adequacy is overwhelmingly positive.

This doctoral thesis's initial research stage quantified the channel's primary uses through a quantitative survey-based research design with the participation of 912 channel users. The results showed that the primary uses of the channel are for entertainment and education, with respective positive use frequencies of 87.2% and 72.7%. When evaluating the professional distribution among users, the main groups that rely on the channel for educational purposes are pre-university teachers, university students, and junior electrical engineers.

Furthermore, a qualitative evaluation was conducted based on open participation from 524 channel users, yielding additional insights. First, Figure 19 underscores the key concepts about participants' views on the educational use of *Sígueme la Corriente* channel and its videos, along with the frequency for each highlighted word.

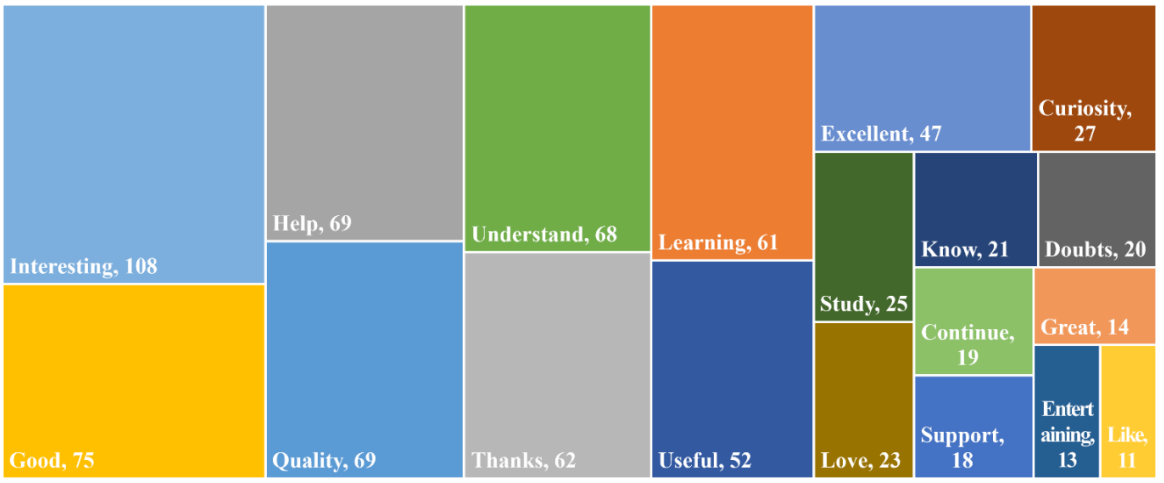


Figure 19. Treemap for key concepts in interviews, and their frequency.

The primary keywords can be sorted under use perception (interesting, help, understand, etc.), and quality perception (good, quality, excellent, etc.). A selection of pertinent excerpts is underscored as follows:

> "I watch all the channel's videos because they are interesting, and I always know that I will learn something new", said Participant 205. Participant 187 elaborated, "Videos are of excellent quality, and explained concepts are understood immediately". Moreover, Participant 49 mentioned, "I think these videos are a good complement, and they help reinforcing teacher's explanations". Finally, from the perspective of professionals in the electrical engineering sector, Participant 115 affirms, "Contents are very good, and they help us as professionals remembering information that, with time, has been forgotten".

Moreover, Figure 20 is intended to show the perceived educational value of the channel and its videos, by detecting the cooccurrences of such keywords with relevant codes for educational use. Participants mainly highlighted the following codes with more than 20 cooccurrences: "understand", "learning", "knowledge", "interesting" and "explanation".

Some relevant testimonials are extracted as follows:

> "The channel is excellent, and it has helped me understand topics that I did not conceptually understand at university", said Participant 138. Participant 12 added, "They are unique videos. They help me understand topics that at first glance seem like an ordeal". In conclusion, Participant 314, a university student, states: "Your videos are of great importance for my academic life. Besides having didactic contents, they are also entertaining. Voice and tone used are pleasant. Filmic quality is good, though it could be improved in illustrative aspects".

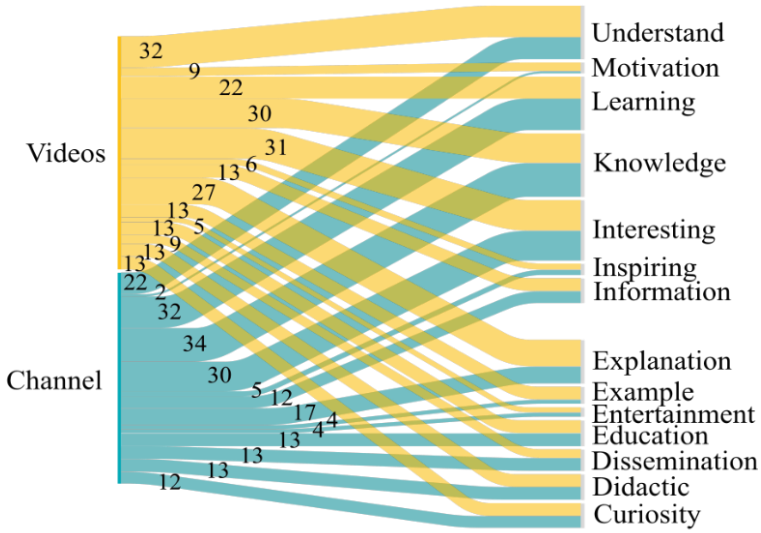


Figure 20. Sankey diagram for the main educational use codes related to "videos" and "channel" keywords.

The evidence gathered indicates that the subjective perception of the educational value of *Sígueme la Corriente* is predominantly positive, with further declarations of its beneficial influence on motivation. This substantiates the channel's ancillary utilization as an educational tool, notwithstanding its initial entertainment objective.

RO1.Q2: What is the channel's audience's perception of critical aspects of video adequacy for its integration into educational environments?

In addition to the channel usage trends, several aspects related to users' perception of content and format adequacy are noteworthy, based on their opinion about commonly used descriptors for both aspects. An evaluation of the audience's perception of these descriptors reveals a notably positive user opinion on factors such as production quality, video length, pace of explanation, accuracy and completeness narrator's confidence, and engaging communication style.

Concerning the perception of the channel's content rigor, a significant correlation has been identified between its educational use and the perception of rigor as a crucial parameter. However, even a more robust correlation has been found in those that use the channel with dissemination and entertainment purposes. Therefore, this suggests that, for the channel's

audience, rigor is not as characteristic from the utility perspective as it is from the entertainment perspective.

Moreover, the results indicate a correlation between those who use the channel for educational purposes and the perception that its technical level suits their needs. Additionally, when assessing the usefulness of videos in satisfying the understanding of topics of interest, we found an exceptionally positive response with a score of 4.58 (on a scale from 1 to 5). These results are practical demonstrations of the potential of videos to facilitate comprehension of abstract complex concepts typically found in STEM education. These insights can be linked to the conclusion that the channel's contents are perceived as appropriate for pedagogical integration regarding content adequacy.

Furthermore, the perception of engagement as an evaluation parameter for the presenter's communication style has been highly rated by participants (with a score of 4.61 over 5). The perception of illustrations, explanations, and examples' usefulness is also positive, aspects that contribute to long-term learning and better retention.

Our results have also revealed a strong correlation in users' perceptions of several video format aspects: communicative abilities, technical level, and artistic integration to illustrate technical concepts. These correlations indicate how content and format aspects are interlinked in the construction of an overall perception of the adequacy of videos for educational purposes.

From a qualitative perspective, Figure 21 represents a Sankey diagram detecting the main subjective reactions to the "level", "quality" and "content" keywords related to the channel's videos.

Regarding the difficulty or easiness of the explained concepts, several reactions highlight that they are both likable and useful (with 7 and 6 respective cooccurrences among received participations). As per the perceived quality of videos shared in Sígueme la Corriente, it is considered good, interesting, and excellent (associated with 26, 9 and 7 respective cooccurrences). Finally, contents are mainly valued as good, interesting, and likeable (with 23, 19 and 12 respective cooccurrences). Some extracts are presented hereafter:

> **Level:** "Videos are adequate for university levels. It is important that an adequate level of technical words is maintained for the degree, without the pretentious and incomprehensible language of some teachers", said Participant 160.
>
> **Quality:** Participant 371 said that "videos are of very good quality. It would be interesting that a playlist is created in the channel with videos of more

technical concepts that help significantly to electrical engineering education".

Contents: Participant 414 specifies that "I think this channel is very didactic, interesting, and full of useful contents for both professionals in the field of electricity, and students", to which Participant 420 also includes "The contents are of very good quality, resources are excellent and, personally, they help me remembering concepts of my degree (industrial engineering)".

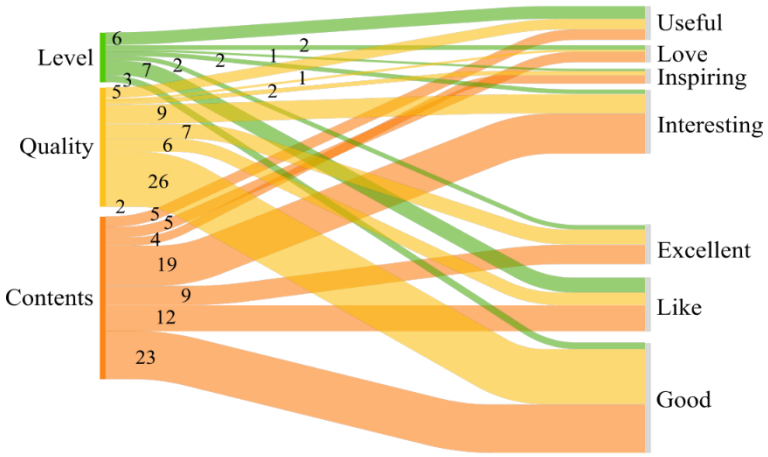


Figure 21. Sankey diagram for the main 'opinion' codes related to 'level', 'quality' and 'contents' keywords.

RO1.Q3: What is the general opinion of the channel's audience about integrating pedagogical videos in education?

Finally, assessing the audience's view on the impact of integrating instructional videos into education, the majority believe that educators should be equipped with more skills in video production for their classes (85.2% positive responses). This sentiment aligns with the United Nation's Sustainable Development Goals (SDG) indicator 4.4.1 for educational quality, which aims to significantly boost the number of youths and adults possessing relevant ICT skills. The overall initiative of *Sígueme la Corriente* seeks to further this aim by creating specific educational materials within technology integration frameworks like CoI and TPACK, together with monitoring educators' digital competence through DigCompEdu. Moreover, this project implicitly contributes to SDG 4.7.1's objective, which emphasizes equipping all learners with the knowledge and skills necessary for promoting sustainable development. *Sígueme la Corriente* specifically targets this promotion of sustainable development in all its videos, given its particular focus on energy and sustainability.

Regarding the potential future use of educational videos, there's no consensus on the notion that instructional videos could entirely replace traditional, in-person education. Only 25.7% responded positively to this idea, while 50.1% responded negatively. The remaining 24.2% held a neutral stance. University student perception results reveal a split opinion, with 50.3% leaning towards rejecting the idea of completely replacing classroom instruction with media resources. This partial resistance to entirely replacing traditional in-person education with video format, coupled with the overall prior evaluation of user perception of video benefits, suggests that students recognize and prefer videos as an auxiliary educational tool. This tool could not only aid in understanding the knowledge presented in specific subjects but also stimulate an increase in motivation and interest in its content.

There is an overall positive perception on the idea that didactic videos could help enhancing education quality (with 96.5% of positive responses). These results support the notion that audiovisual resources used for informal scientific communication may serve dual roles: educational tools and entertainment sources. They also highlight the positive perception of users regarding their potential value to contribute to formal education settings. These findings underscore the opportunity to incorporate formal strategies into STEM dissemination channels to create educational content effectively.

4.3 Contributions to RO2

Considering the outcomes of RO1, it has been verified that the channel's contents fulfilled an educational need even though they were not designed for such use. Therefore, RO2 is focused on designing dissemination videos optimized for educational use. These videos would be integrated in real classroom scenarios during ERL. Figure 22 shows how RO2 is related to the evaluation of metrics to optimize the educational value of videos, to evaluate the potential of dissemination resources in education, to the creation and assessment of videos to be used as didactic support during ERL scenarios, and to detect if videos have an impact on fostering interest in STEM disciplines.

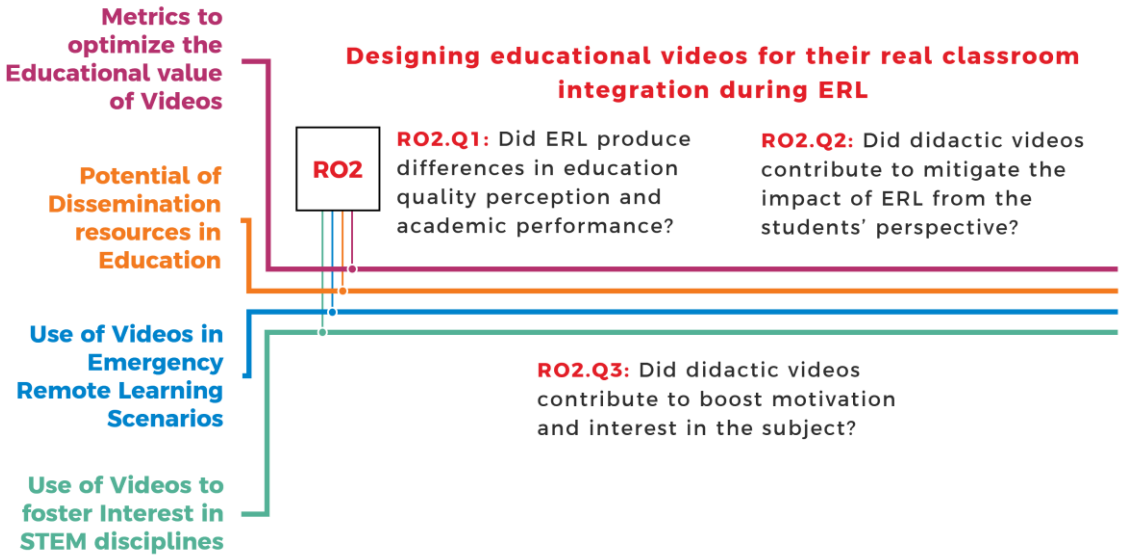


Figure 22. Research lines, Research Objective 2, and questions within it.

The insights contributing to RO2 belong to the second research stage of this doctoral thesis, which was consolidated in the second article of the compendium (Lijo, Quevedo, Castro, et al., 2023). This case study was developed during the academic courses 2019, 2020 and 2021 within the "Electrical Machines I" course at the School of Industrial, Aerospace and Audiovisual Engineering of Terrassa, at *Universitat Politècnica de Catalunya* (UPC), covering pre-ERL, ERL and post-ERL scenarios. The following subsections present the main contributions to the research questions building up RO2.

RO2.Q1: Did ERL produce differences in education quality perception and academic performance?

The SEEQ survey (see the subsection 3.3.2 for more information about the instrument) revealed a notable decrease in Learning and Enthusiasm factors, primarily due to a diminished understanding of the subject matter and a lessened interest in the professor's presentations due to the learning environment. The improvised ERL environment may have impacted the professor's comfort, affecting their ability to deliver engaging presentations such as normally achieved in presential classes. This is especially significant, as it suggests that ERL influenced students' perception of their learning outcomes and their professors' capacity to stimulate their motivation and interest in the subject.

Contributions:
Building up on the research gaps

Although there were slight variations in the evaluable activities' performance, there were no significant differences between the pre-ERL and ERL situations, except for the practical exam 1. This aligns with the initial challenges of ERL, which in this case study had a more significant effect on procedural learning than on conceptual learning. The students' adaptation and acceptance of the situation during the course progression also align with the performance improvement from mid-semester to end-semester examinations during ERL observed in the study.

As for active participation during synchronous classes, the SEEQ survey disclosed an increase from pre-ERL to ERL, primarily linked to the professors' heightened proactivity in encouraging students to express their ideas, ask questions, and engage in class discussions. This is a standard practice in the "Electrical Machines I" course at UPC, which is consistently taught with a high student participation component. However, the isolation and new learning environment imposed by ERL prompted the professor to further emphasize the importance of group interaction.

Despite this being true for synchronous classes, it may not reflect the entire learning experience. The qualitative assessment has identified other adverse impacts of ERL, including a perceived decrease in tutored learning and concentration. A noticeable reduction in the professor's accessibility was also reported in the SEEQ results, consistent with the qualitative findings of a perceived decrease in tutored learning. This might also be connected to the grade and performance decline reported by some students. Feedback on graded assignments and the instructor's emphasis on key concepts for evaluation also decreased during ERL.

However, the overall assessment of the degree's professors conducted by the Electrical Engineering Department confirms that the "Electrical Machines I" professor is among the most valued professors of the degree during pre-ERL, ERL, and post-ERL scenarios, precisely due to the pedagogical tools used for online teaching. A similar case study performed in other subjects might unveil a higher impact of ERL among the different scenarios. This appreciation might be linked to the perception of the course's assignments. The effect measured through the SEEQ primarily refers to proposed reading and homework, which students found significantly less valuable. However, the educational videos provided during the course significantly impacted on students, as reported through the qualitative assessment. These contributions of the proposed didactic videos are presented in the following subsection.

RO2.Q2: Did didactic videos contribute to mitigate the impact of ERL from the students' perspective?

The quantitative methodology in this article aimed to assess the impact of ERL on students' perception of education quality and performance. However, with only this data, it is not possible to isolate the effects of videos in such a scenario. This is why a mixed methods approach has been designed.

Despite the previously mentioned adverse impacts of ERL, subtleties extracted from the qualitative assessment indicate that there are also positive impacts for students participating in the study. These are primarily related to an increase in independent study encouraged by video-assisted active learning. Some participants even reported an increase in their performance and interest in the subject during ERL, thanks to the new opportunities for self-paced learning and the increase in study time promoted by the provided video resources.

Participants expressed that videos helped them understand the subject's concepts and were a beneficial supplement to the professor's explanations. This is mainly because they allowed for repeated viewing of conceptual explanations and resolving doubts at a self-paced rhythm with didactic explanations. As revealed during the initial stage of qualitative assessment, an average of 6.33 (SD 2.16) out of 9 videos were watched for doubt-solving purposes at a variable pace depending on the need for conceptual aid.

This study shows that conceptual learning might benefit from video integration with concept discussion and problem resolution in tutored activities during class. This reasoning explains the differences between Theory Exams and Problems Exams, where conceptual learning promoted by video integration is found to be useful in mitigating ERL impact for both Theory Exam 1 and Theory Exam 2. The primary detected impact of ERL on academic performance relates to problems and laboratory tests. At the same time, in theory examinations, videos might have served as a mitigating tool by supporting conceptual learning. It is worth noting that end-semester theory examinations typically yield better results than mid-semester ones, as students incorporate and assimilate concepts throughout the course, suggesting an inherent improvement in performance.

Students emphasized that the proposed didactic videos enabled them to visualize abstract concepts more clearly, enhancing the didactic experience. This is supported by CTML, as the dual channel (visual and auditory) reduces the cognitive load the student is exposed to, and visual animations aid in understanding abstract ideas (refer to the subsection 1.1.2).

Our findings from the qualitative assessment, along with their alignment with the observations from the quantitative assessment and literature, suggest that didactic videos could mitigate some of the negative effects of ERL scenarios. This is mainly due to their support for conceptual learning and their contribution to increasing study time and self-paced learning. However, they were insufficient to fully offset such an unprecedented paradigm shift. Instead, they acted as a cushioning measure.

RO2.Q3: Did didactic videos contribute to boost motivation and interest in the subject?

The introduction of didactic videos in classrooms has significant implications for boosting motivation and interest in STEM subjects, as shown by the results of this study. These results are also consistent with current literature. Often rich in content and interactive elements, videos provide a dynamic and engaging way of presenting complex STEM concepts. They allow students to learn at their own pace, as they can pause, rewind, and re-watch the videos as needed. This autonomy in learning can significantly enhance students' motivation. Moreover, didactic videos often feature real-world applications of STEM concepts or their professional applications, which can pique students' interest and show them the relevance and potential impact of what they are learning.

As previously discussed, while ERL significantly influenced students' perception of the quality of education, didactic videos served as a counterbalance in this case study, particularly in providing conceptual support throughout the course. This had a distinct impact on academic performance in theoretical exams. However, the implications of didactic videos became even more pronounced when focusing on motivation and interest in the subject.

The integration of didactic videos successfully sparked such interest, as underscored by participants in the qualitative assessment. This is primarily due to the videos' ability to visualize abstract concepts, which are prevalent in STEM disciplines and, specifically, in electrical engineering. These factors align with the premise of our study, where the developed videos incorporated an enhanced version of phasor diagrams, made possible by including animated drawings. Moreover, students appreciated that an active professional produced the videos, as they contained intriguing practical explanations that enabled them to uncover the professional applications of electrical engineering. This helped to foster a comprehensive understanding of the degree's content, as

well as to establish connections between critical concepts that would otherwise be presented in isolation and without any links.

In summary, the qualitative feedback indicates that integrating these didactic videos had a positive impact on motivation and increased the students' interest in the subject matter.

4.4 Contributions to RO3

The previous sections demonstrated, with RO1, that a dissemination YouTube channel can be having an involuntary side use as an educational resource; and, with RO2, how dissemination videos optimized for educational use can positively mitigate ERL scenarios. Moreover, these videos can impact aspects such as academic performance, the perception about education quality and both students' motivation and interest in STEM disciplines. As a following step, RO3 has been focused on the comparative analysis of the educational and dissemination use of a YouTube channel. Figure 23 shows how RO3 is related to the evaluation of metrics to optimize the educational value of videos, and to evaluate the potential of dissemination resources in education.

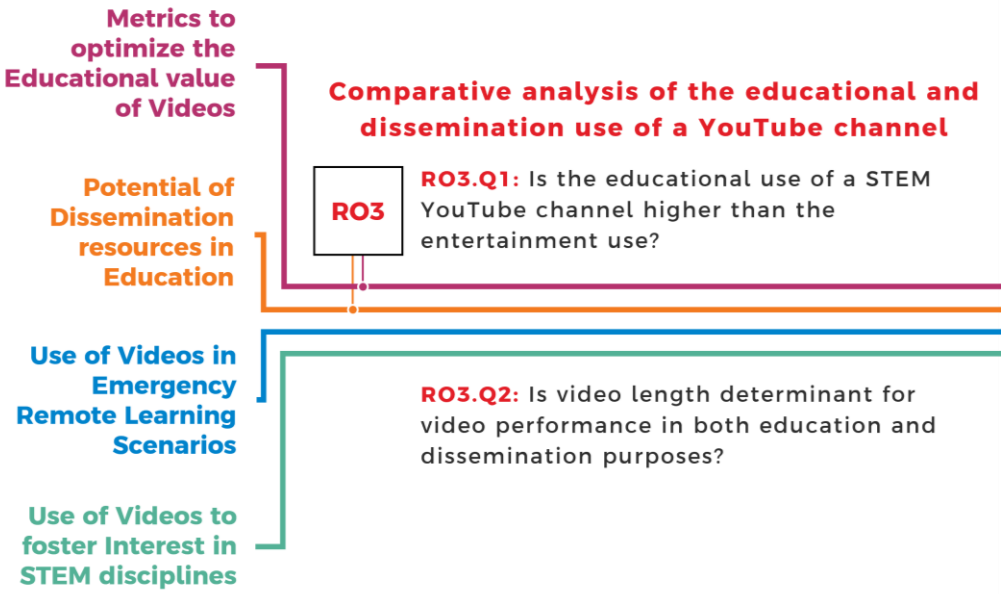


Figure 23. Research lines, Research Objective 3, and questions within it.

The insights contributing to RO3 belong to the final research stage of this doctoral thesis, which was consolidated in the third article of the compendium (Lijo et al., 2024). This case study was developed considering *Sígueme la*

Corriente insights for a 6-year period, covering from 2017 to 2022, and considering the sample of 147 videos and the data acquired from the channel's 4,268,071 views. The following subsections present the main contributions to the research questions building up RO3.

RO3.Q1: Is the educational use of a STEM YouTube channel higher than the entertainment use?

This RQ examines the use of a STEM YouTube channel focusing on views, average view duration, subscribers count and interaction parameters (comments, shares, likes and dislikes). These are the main metrics describing a YouTube channel's use. In this sense, the case of *Sígueme la Corriente* has shown how educational content is by far more viewed and interacted with than dissemination content. A significant correlation has also been found between awareness and interaction parameters, meaning that impressions, views and subscribers are correlated with comments, shares, likes and dislikes.

Results show that educational videos have a longer average view duration and more views than dissemination videos, indicating that the channel's current primary use is for educational purposes. About 67% of total views and 73% of playlist starts are related to educational content.

The interaction metrics (comments, shares, likes, or dislikes) experienced a trend change after August 2020, possibly due to the reconceptualization strategy followed in the channel that included the creation of educational content. The channel averages 4.95 daily comments, with a peak of 149 comments on December 3rd, 2020. However, there is a clear tendency change in reconceptualization phase with a mean value of 7 comments per day. Educational videos receive 2.89 times more comments than dissemination videos, potentially representing a greater will to ask questions or share perceptions with the video creator and pairs in the case of educational use. Shares also show a similar pattern, with an average of 6.8 shares per day during the presentation and consolidation stages, and 54.67 shares per day during the reconceptualization stage. Educational videos are shared 3.75 times more often than dissemination videos.

Likes and dislikes also confirm the higher use of educational videos. During the presentation and consolidation phases, the channel received an average of 58.03 likes per day, while in the reconceptualization phase, it received an average of 160.15. Educational content received 3.2 times more likes than dissemination content. However, educational content also received more

dislikes, probably due to their higher exposure. It is noteworthy, though, that educational content received fewer dislikes per visit compared to dissemination content. Unlike other parameters such as comments or visits, likes and dislikes have a direct meaning since they are representing a positive or negative evaluation of the audience about the videos' contents and format. Based on both literature and our findings, the factors influencing likes include the explanations' understanding, the presentation of contents, the contents themselves, the efficiency of explanations, the language and voice used by the presenter and the audience's interest in the topic presented. *Sígueme la Corriente* channel aligns well with these factors, as evidenced in previous studies (see the sections 4.2 and 4.3). These previous results highlighted the audience's positive perception of the channel's effectiveness in explaining topics of interest, the appropriateness of visual supports such as illustrations and animations, the adequacy of the technical level of its contents, the adequacy of the pace of videos for concept comprehension, the engaging presenter's communication skills, and the interest of contents developed.

Moreover, regarding subscribers, the channel receives an average of 67.14 daily, with educational content attracting 4.72 more subscribers than dissemination content. This results in an average of 2007 subscribers per educational video, compared to the 425 for each dissemination video.

Overall, the channel's audience shows a clear preference for educational content, as also confirmed by previous analyses. The initial exploratory analyses covering both presentation and conceptualization phases (see the section 4.2) evidenced the initially involuntary use of the channel's dissemination contents for educational purposes, and an overall positive perception of such contents. Moreover, the audience highlighted the channel's value for understanding and learning complex concepts in engineering, claiming that it also enhanced their motivation and interest in such discipline. Responding to such demands, the reconceptualization phase has addressed the audience's educational needs, and the contents resulting from such considerations have performed much better than the classic dissemination format previously offered by the channel.

This preference for educationally compatible content could be significant for other content creators, demonstrating how STEM YouTube channels can be considered suitable for educational use. It also underscores how content specifically designed for educational use can boost a channel's growth, when special consideration is focused on its curricular alignment and format optimization.

RO3.Q2: Is video length determinant for video performance in both education and dissemination purposes?

The widespread idea is that shorter videos are often preferred by the audience over longer ones. However, this might become a dangerous general rule because does not consider how different contents might require different time investments for a proper explanation and understanding. Instead, explanation efficiency is more suitable for adequately addressing the need to shorten videos to the extent that their content allows for a proper explanation. This implies that an optimal target of video length should be flexible within certain margins, as it needs to adapt to the complexity and extent of explained concepts.

Most videos on *Sígueme la Corriente* channel are between 5 and 15 minutes long, catering to the content's need for comprehensive and lucid explanation. This applies to 69% of educational videos and 63% of dissemination videos. Optimizing content delivery is a key goal during production, especially for educational videos. Previous channel analyses indicate that 88.4% of users find the video durations satisfactory.

While this study has not found correlation between video length and view count, a significant correlation exists between video length and average view duration. This suggests that video length affects viewer retention and the video's educational success. An inverse correlation shows that shorter videos are watched for a longer time, both in educational and dissemination content. As per Figure 24, the average view duration for most educational videos is between 5 and 15 minutes, which remains over 50% of the video length.

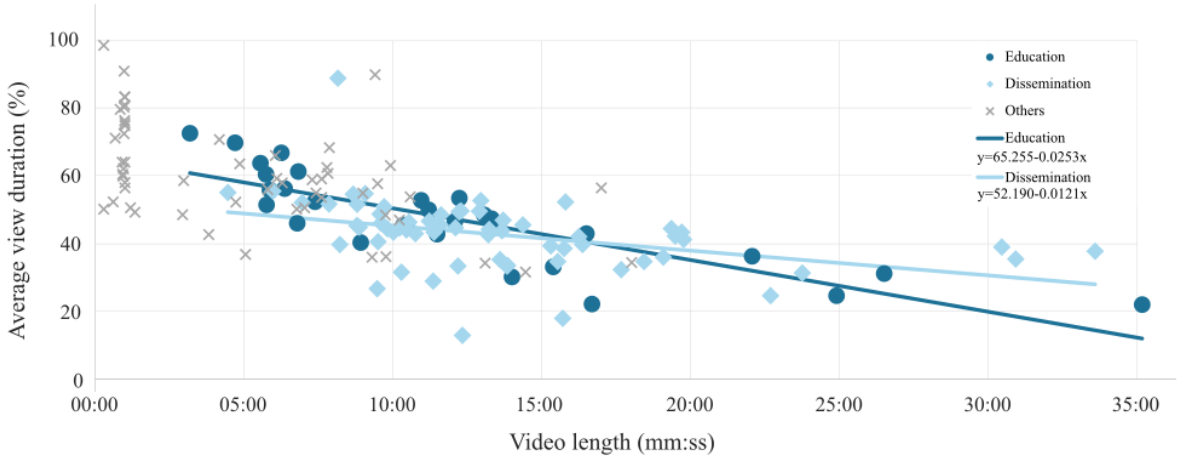
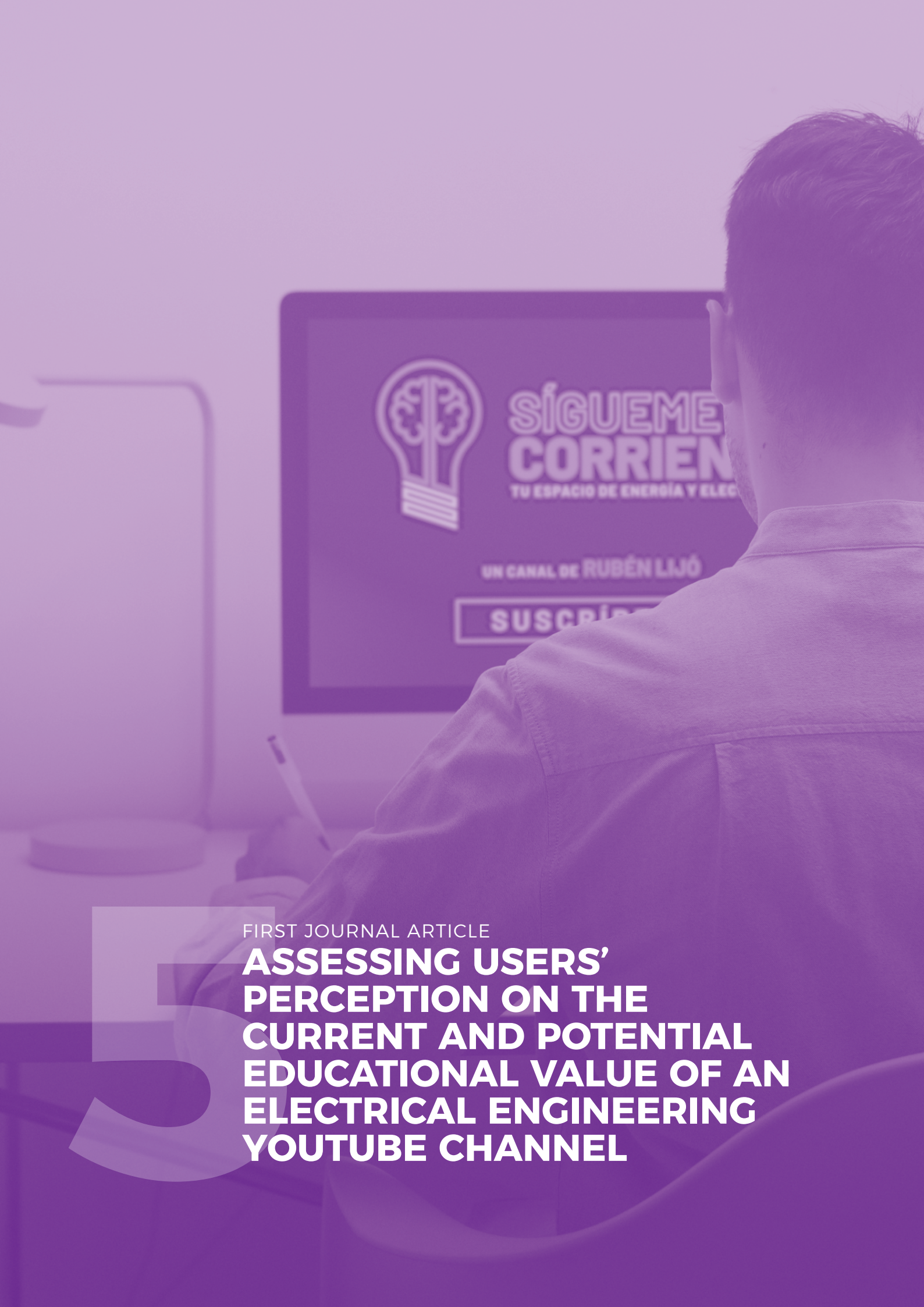


Figure 24. Linear regression between video length and view duration per content category.

As evidenced by these results, educational content is more influenced by video length than dissemination content. This could be because educational videos are designed to explain specific concepts or provide succinct descriptions. Notably, educational content shows less dispersion in the linear regression model than dissemination content, likely due to the consistent characteristics across all educational content on the channel. On the other hand, the format of dissemination videos may vary to cater to curiosity and entertainment and to optimize reach for each topic. Conversely, educational videos on the channel maintain a standard format, aiming for curricular alignment, focused explanations, high-quality animations and visualizations, and supportive mathematical explanations.

In conclusion, according to our results and contrasted with the literature, video length significantly impacts video performance in terms of retention rate, which is a key measure of engagement. This effect is especially pronounced in educational content, where the ideal video length seems to be between 5 and 15 minutes. It is highly recommended to consider this length margin as a flexible margin to ensure a clear and efficient presentation of each video's contents.



FIRST JOURNAL ARTICLE

ASSESSING USERS' PERCEPTION ON THE CURRENT AND POTENTIAL EDUCATIONAL VALUE OF AN ELECTRICAL ENGINEERING YOUTUBE CHANNEL

5. First journal article: Assessing users' perception on the current and potential educational value of an electrical engineering YouTube channel

5.1 Article's Main Information

- **Journal:** IEEE Access (Volume: 10).
- **Section:** IEEE Education Society Section.
- **Indexed in:** IEEE Access is included in the Clarivate Analytics Web of Science (WoS - JCR), which includes Science Citations Index Expanded, Journal Citation Report/Science Edition, and Current Contents Engineering, Computing and Technology Edition. IEEE Access has an impact factor of 3.9 (Q2), an Eigenfactor of 0.32872, a five-year impact factor of 4.1, and an immediacy index of 0.7 (per 2022 JCR). This journal is also included in Scopus, with a CiteScore of 9 (per 2022 Scopus) and a Scimago Journal Rank of 0.926 (Q1) (per 2022 SJR). Moreover, IEEE Access is also indexed by Inspec, Ei Compendex, and EBSCOhost. It is also listed in the Directory of Open Access Journals (DOAJ).
- **Publisher:** Institute of Electrical and Electronics Engineers (IEEE).
- **Pages:** 8948 – 8959.
- **Date of final publication:** 26 January 2022.
- **ISSN:** 2169-3536.
- **DOI:** 10.1109/ACCESS.2021.3139305.
- **Video abstract:** this article has a video abstract available through its online publication interface at IEEE Xplore. Access available at: https://doi.org/10.1109/ACCESS.2021.3139305.

Cite this article as: R. Lijo, E. Quevedo, J. J. Castro and R. Horta, "Assessing Users' Perception on the Current and Potential Educational Value of an Electrical Engineering YouTube Channel," in IEEE Access, vol. 10, pp. 8948-8959, 2022, doi: 10.1109/ACCESS.2021.3139305.

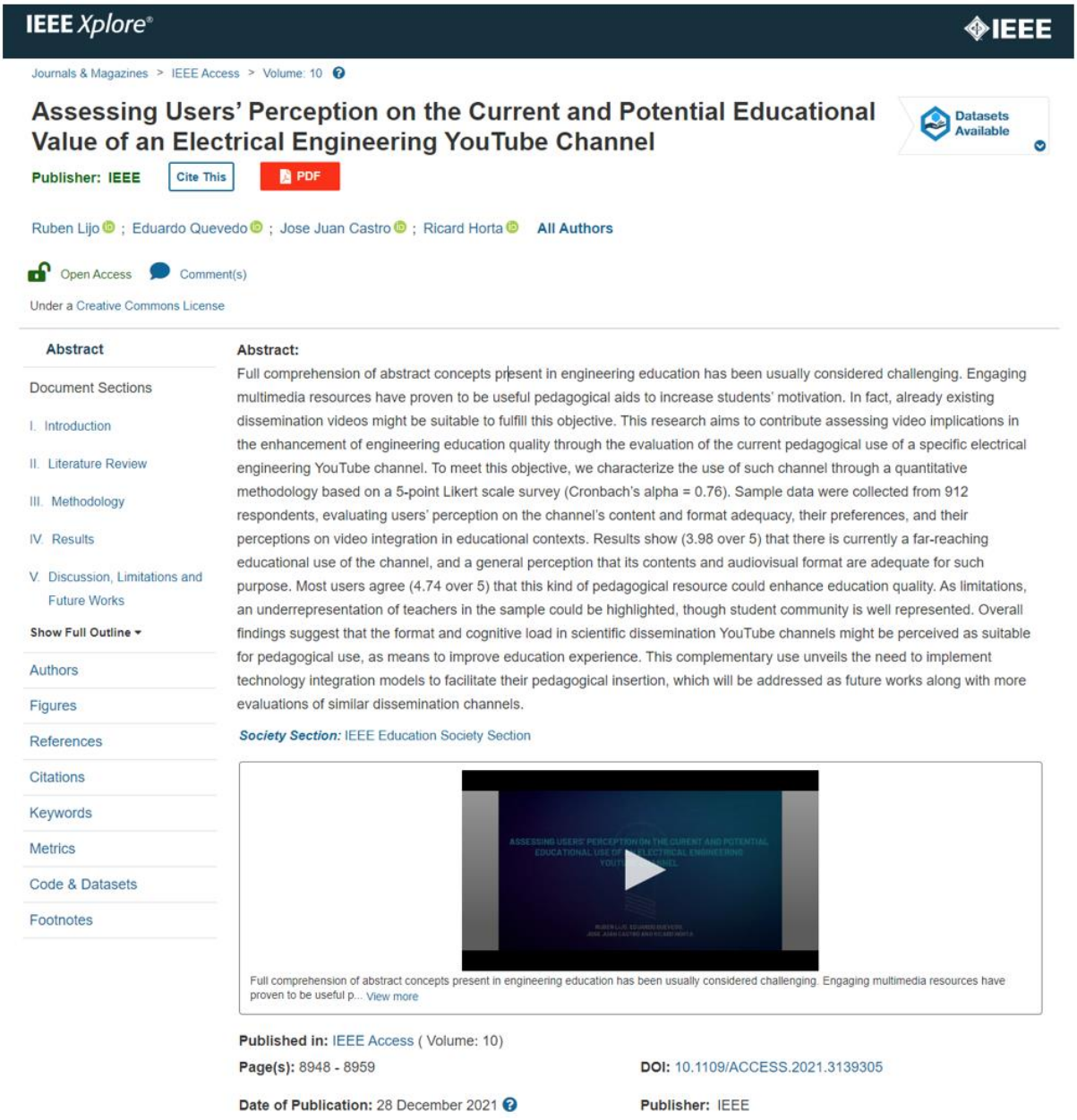


Figure 25. Online publication of the article 1 at IEEE Xplore.

5.2 Embedded Article

IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

IEEE EDUCATION SOCIETY SECTION

Received November 22, 2021, accepted December 25, 2021, date of publication December 28, 2021,
date of current version January 26, 2022.

Digital Object Identifier 10.1109/ACCESS.2021.3139305

Assessing Users' Perception on the Current and Potential Educational Value of an Electrical Engineering YouTube Channel

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This work was supported by the University Foundation of Las Palmas (FULP), Training of Trainers through the e-Tutor Project under Grant 240/088/1173.

ABSTRACT Full comprehension of abstract concepts present in engineering education has been usually considered challenging. Engaging multimedia resources have proven to be useful pedagogical aids to increase students' motivation. In fact, already existing dissemination videos might be suitable to fulfill this objective. This research aims to contribute assessing video implications in the enhancement of engineering education quality through the evaluation of the current pedagogical use of a specific electrical engineering YouTube channel. To meet this objective, we characterize the use of such channel through a quantitative methodology based on a 5-point Likert scale survey (Cronbach's alpha = 0.76). Sample data were collected from 912 respondents, evaluating users' perception on the channel's content and format adequacy, their preferences, and their perceptions on video integration in educational contexts. Results show (3.98 over 5) that there is currently a far-reaching educational use of the channel, and a general perception that its contents and audiovisual format are adequate for such purpose. Most users agree (4.74 over 5) that this kind of pedagogical resource could enhance education quality. As limitations, an underrepresentation of teachers in the sample could be highlighted, though student community is well represented. Overall findings suggest that the format and cognitive load in scientific dissemination YouTube channels might be perceived as suitable for pedagogical use, as means to improve education experience. This complementary use unveils the need to implement technology integration models to facilitate their pedagogical insertion, which will be addressed as future works along with more evaluations of similar dissemination channels.

INDEX TERMS Electrical engineering education, educational activities, videos, YouTube.

I. INTRODUCTION

During 2020, UNESCO reported that educative centers' closure due to covid-19 pandemic affected an estimate of 1.5 billion students worldwide, which represents approximately 90% of global student population [1]. Several authors have highlighted lockdown implications in education, agreeing that technology unavailability and lack of previous experiences with online learning were relevant aspects increasing its impact [2]–[5]. In this situation, online learning had an essential role in ensuring the continuity of academic activity, but this new paradigm carries some challenges that might affect education quality, such as non-universal technological access or the possible lack of an adequate home environment, both key aspects when online education is involved [4], [5].

The current context, as clearly evidenced during covid-19 pandemic, is unfortunate for all students, [4], [5], but it is specially challenging in disciplines with wide presence of abstract concepts such as Science, Technology, Engineering and Mathematics (STEM) [6].

An additional challenge specifically found in engineering students is the ability to properly understand the connections

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

between subjects and being able to integrate them in the big picture of the degree and its professional applications [7]. In those regards, the integration of Information and Communications Technologies (ICT) in distance education plays a facilitating role that allows creating virtual communities that boost learning through search and interaction among pairs. Through the creation of these communities, students are involved in social, cognitive and lecturer's presence, which are the three main constructs for a successful constructivist interaction, as defined by the Community of Inquiry (CoI) paradigm [8], [9].

Engineering education quality could be enhanced by the improvement of abovementioned weaknesses, and the use of audiovisual materials might be a complementary solution. Research in pedagogical use of video material provides numerous references of its enhancement of parameters such as long-term retention of concepts [10], comprehension and deeper learning [11]. Descriptive images and animations, usually included in educational videos, are helpful for complex and abstract concepts understanding, as they provide complementary meaning to theoretical explanations, and they can also be reproduced by students when incorporated as a new problem-solving strategy [12]. These educational videos often focus on the creation of interest and show examples of practical applications, which also promote students' engagement and develop their critical thinking ability [13]. Such characteristics also make them suitable for the teaching of soft skills in engineering education [14], using them as key format in gamification strategies, as well as supportive resources in learning environments and content delivery resources in Massive Online Open Courses (MOOC).

Additionally, when referring to affective deficiencies, videos are also proven to be an effective support on students' motivation and on reducing academic stress, as well as anxiety levels [15], [16]. These aspects are highly related to dropout rates, which are specifically elevated in engineering disciplines [17]. Videos not only can be accessed anywhere and anytime, but also students are in control of their pace. Moreover, new free time in synchronous classes due to video integration, that would otherwise be used for topics introduction and the resolution of basic initial questions, can now be dedicated to other activities that promote active learning from those educational videos [18]. An example of such activities could be the implementation of problem based learning methodologies, as studied in previous research with positive results for teaching-learning processes [19]. Another successful example would be the use of instructional videos in engineering flipped classrooms, where they have proven to have an overall positive effect on student awareness of real-life applications [20]. Authors such as Shoufan [21] specifically highlight YouTube videos as key backup material in active learning strategies, highlighting its success in students' engagement and perception for purposes such as step-by-step learning procedures, as well as descriptive and conceptual explanations.

The development of such practical activities is crucial in online learning environments, as they are able to enhance online participation. As previously stated, CoI paradigm acknowledges this active component as vital to develop a successful and sustainable online learning experience [8]. Other models such as Technological Pedagogical Content Knowledge (TPACK) [22], [23], also describe the continuous knowledge improvement of lecturers as essential to design useful constructivist educational environments, through a successful integration of current technology.

Trying to continue studying the implications that audiovisual material might have in the described context, this article focuses on currently online available engineering communication videos, and the role they might play in higher engineering education environments. Our case study is based on *Sígueme la Corriente*, a Spanish channel specialized in electrical engineering [24]. This study is focused on the assessment of the channel's user preferences towards its educational integration. Therefore, the following research questions have been established: are YouTube dissemination videos being integrated in electrical engineering education? In that case, what are their most valued features for such pedagogical use?

Consequently, three specific objectives have been defined for this study:

(1) Detect if such channel, created with the purpose of entertaining the general public through technological dissemination, can be having a side use as educational resource.
(2) Evaluate the perception of its audience on key aspects for video adequacy to be integrated in educational environments (format and content adequacy).
(3) Evaluate the opinion of its audience on the integration of pedagogical videos in education.

Aligned with the aims of the study, results have shown an important pedagogical use of the channel mainly from pre-university teachers, university students and junior electrical engineers. Format and contents are highly rated as adequate for its integration in educational contexts. Additionally, the channel's users show a remarkable tendency to consider videos as a successful resource to enhance education quality. Overall, the findings of this study provide useful insight about the potential suitability of the channel for the creation of future sections specifically designed to be used as educational aid, in service of the needs detected in different Electrical Engineering degrees.

The paper is organized as follows: the currently available literature related to our research is presented in section II. The sample considered and the survey developed to characterize the audience is detailed in section III. Section IV introduces the main results, discussed in section V. Conclusions are highlighted in section VI.

II. LITERATURE REVIEW

This study aims to contribute to the integration of audiovisual resources as means of improving online learning of STEM

disciplines and dynamize constructive learning strategies. These resources might constitute a helpful pedagogical aid when used within the context of CoI model [8], enhancing the educational experience by the improvement of parameters such as content engagement, interaction with pairs through video-related activities, and self-regulated learning. The proactive use of video resources might create a self-motivational environment able to promote students' engagement and goal setting [16]. Furthermore, ICT-TPACK model is based on constructs that could also be benefited by the integration of videos as pedagogical aid [25], [26]. The ultimate goal of this educational model is the creation of new scenarios that could improve teaching-learning processes using ICT, through the analysis and enhancement of the interactions between technology with contents and pedagogical methods. Both CoI and TPACK models can benefit from each other fostering a constructivist perspective of knowledge, focused on the student [27].

Our research takes over the existing literature on social network and video integration in educational contexts. Audiovisual resources, and particularly those currently available in YouTube as the most used platform [28], [29], are showing several benefits as a pedagogical complementary tool, that we intend to explore in this section. Negativity towards new processes is acknowledged by Zachos *et al.* [30] when referring to online social networks integration in higher education, though they also provide wide evidence on their positive contributions as didactic complementary tools [31].

However, results from previous research [32] show that teachers did not present resistance when incorporating ICT into their lectures. A 5-point Likert scale survey was developed in this study, where teachers from Universidad de Las Palmas de Gran Canaria (ULPGC) expressed their opinion on ICT tools as supporting resource for attendance-based teaching, showing how parameters such as materials accessibility and communication were importantly enhanced. Increase of motivation and engagement are also key benefits from integrating ICT in higher education, as exposed by several authors [11], [21], [29], [33].

As pointed out by Lee and Lehto [34], YouTube didactic value might not be easily recognized by both students and teachers due to its focus towards entertainment instead of education. Yet, despite this is an extrinsic task goal for the platform, research driven by Černá and Borkovcová [35] also show that there is clear prevalence from YouTube when referring to video application in educational contexts. Moreover, Gil-Quintana *et al.* [33] studied some of the characteristics of the communicative model widely used by youtubers. Furthermore, they also considered the interaction with followers and high engagement rates. They concluded that these parameters might turn youtubers in a preferred academic reference for students. The connective nature of YouTube also makes it an interesting candidate to be increasingly integrated in educative contexts, as it contributes to increment social-skill building in students through interaction and discussions [31], [36].

All abovementioned benefits could merge in a resulting student performance increase. D'Aquila *et al.* [37] developed a case study confirming the improvement of the academic performance in a sample of 246 individuals assessed through a Likert scale questionnaire and analyzed by a multivariate regression test. These findings are also coherent with results from Expósito *et al.* [38], whose research show how instructional video integration in teaching activities resulted in a significant reduction of the probability of achieving low test scores.

As previously exposed, YouTube might constitute an ideal complementary tool for educational contents. However, the issue of pedagogical video integration in university STEM education is far to be completely solved. Several authors have pointed out the role of teachers as content facilitators more than content creators, acknowledging the real challenge of selecting adequate channels and videos [35], [39]. Therefore, the challenge focuses on teachers being able to select videos whose format and cognitive load is appropriate for students and course needs, which is not straightforward due to the excess of information and unregulated contents, that results in the appearance of the decision paradox.

Some strategies have proven to be significantly useful. Brame's research [18] suggests that it is crucial to correctly measure the cognitive load of recommended didactic videos, boosting active learning linked to those resources and maximizing student engagement by selecting easy-to-follow video formats. Tadbier and Shoufan [39] acknowledge the challenges associated with adequate channel and videos selection, and suggest the creation of trustworthy rankings that could be useful to aggregate didactic YouTube channels. Additionally, other authors [34], [40], [41] suggest the use of rubrics as guidelines for adequate video selection, highlighting aspects such as accessibility, production quality, explanation rhythm, accuracy and completeness, narrator confidence and engaging communication style. In consonance with these parameters, Romero-Tena *et al.* [42] propose the use of a Likert scale questionnaire that helps identifying video suitability in terms of lecturer's perception on abovementioned metrics.

As a further contribution to these challenges and proposals, this article focuses on exploring the perception on the educational value of an electrical engineering dissemination YouTube channel applying the most representative metrics extracted from literature, as exposed in the Methodology section. This analysis is also intended to explore a potential full educational development of the channel, unveiling the benefits of implementing such educational videos in Electrical Engineering degrees with the main purpose of easing the motivation and understanding of complex abstract ideas and wicked problems surrounding engineering challenges as per the energy perspective [43].

III. METHODOLOGY

A. CASE STUDY

This paper presents an analysis of the current and potential pedagogical use of *Sígueme la Corriente* through a

TABLE 1. Questionnaire.

ID	Questions
Q1	I watch the channel's videos the same week they are published
Q2	I watch old channel's videos
Q3	I use the channel with educative purposes
Q4	I use the channel for entertainment purposes
Q5	I use the channel to stay updated on news in the sector
Q6	The selection of topics and contents matches my interests
Q7	The presenter's explanations are attractive and interesting
Q8	Rhythm of videos is adequate for concept comprehension
Q9	The technical level is adequate (I can follow the concepts and I also learn new things)
Q10	The channel's contents are rigorous
Q11	Its contents help me understand topics I'm interested in
Q12	Video's contents are up to date
Q13	Video's duration is adequate
Q14	Audiovisual resources used (images and music) are helpful to understand concepts
Q15	Didactic videos could help enhancing education quality
Q16	Classrooms are well equipped for the projection of didactic videos
Q17	Professors should be provided with competences for the creation of own didactic videos
Q18	Didactic videos can substitute assistance-based education

characterization of its audience and an evaluation of its users' preferences. *Sígueme la Corriente* was created in 2017 with the aim to contribute to Spanish-speaking public with more engineering dissemination contents. It has increasingly reached an audience particularly interested in energy, electricity and sustainability topics.

The channel was not created with an educational purpose; however, comments and views sources suggest that the channel might be having a side use as a pedagogical resource. Hence, this study aims to confirm whether the channel is already being used for such applications, and what are its audience perception on key parameters that would make it adequate for educational use, in consonance with metrics highlighted in Literature Review. Additionally, this study evaluates the perception of the channel's audience on the implications of didactic videos integration in education. For those purposes, a questionnaire has been developed as data acquisition instrument.

B. DATA COLLECTION

The designed questionnaire has considered a quantitative research methodology. A descriptive study is provided using a five-point Likert scale, where scores correspond to the following perceptions: 1 as 'strongly disagree', 2 as 'disagree', 3 as 'neutral', 4 as 'agree', and 5 as 'strongly agree'. The descriptors adopted for the questionnaire have been selected as per the main metrics defined in Morain and Swarts's rubric [40], which are also in consonance with the Technology Acceptance Model (TAM) as implemented by Lee and Lehto for YouTube procedural learning user acceptance analysis [34]. Table 1 shows the designed questionnaire.

This instrument mainly focuses on characterizing *Sígueme la Corriente* users, to be able to determine if there is an existing pedagogical use of its contents. Additionally, a set of questions has been designed to evaluate the audience perception on key metrics related to contents and format adequacy, considering the main parameters mentioned in Literature Review. Finally, a last set of questions is included to assess the audience perception on didactic videos integration in education.

The developed questionnaire was provided to *Sígueme la Corriente* subscribers on July 14th, 2020, and answers were collected for 18 days, until July 31st. The population considered in this study has been 69,829 users, as it was the total amount of subscribers when the survey was closed.

The minimum representative sample is calculated through the Cochran equation [44] with finite population correction (1). It describes the sample size (n) given a targeted confidence level (which provides a score value (Z)), margin of error (ε), population proportion (p), and population size (N). For a confidence value of 95% (1.96 score), a margin of error of 5% and an assumed population proportion of 50%, the minimum sample needed to be representative would be of 383 participants.

$$n = \frac{\frac{Z^2 \cdot p(1-p)}{\varepsilon^2}}{1 + \frac{z^2 p(1-p)}{\varepsilon^2 N}} \tag{1}$$

The questionnaire developed for this study was shared with the channel's audience, achieving a maximum sample of 912 individuals, which exceeds by 529 the minimum required (383) for a 95% confidence level. Though not all questions were answered by the totality of the sample, the minimum sample size has been 849, which is still above the minimum sample size for 95% confidence level.

The collected information is available online through IEEE DataPort [45].

C. DATA ANALYSIS

As means to characterize the sample, and the total audience, demographic questions were included as part of the survey. On the other hand, population data were extracted from YouTube statistics for the period from December 28th, 2016 (when the channel was opened) to July 31st, 2020 (when the survey was closed to the public). Table 2 represents a comparison between the sample and the whole population.

In terms of sex distribution, it is noteworthy that only a 3.9% of the population are women. As per the sample proportion, it seems that women were more willing to answer the proposed survey, since there was a women participation of 7.6%. Moreover, according to Fig. 1, it is clear that the majority of women are in the group between 18-24 years, whereas men age distribution is wider. This is in consonance with the demographic statistics.

Referring to age proportions, it is remarkable that the group between 25 and 34 years old is not correctly represented according to the defined confidence interval. However, the group between 18-24 years (most of them university students as can be seen in Fig. 2) is almost half of the sample (48.68 %), exceeding the upper limit of the confidence

TABLE 2. Comparison between Population and sample information.

Parameter	Sample (95% CI)	Population
Individuals	912	69,829
Men	92.4 % (90.63 – 94.17 %)	96.1%
Women	7.6 % (5.83 – 9.63 %)	3.9%
Individuals age		
Between 13 and 17	9.21 % (7.28 – 11.14 %)	2.2%
Between 18 and 24	48.68 % (45.38 – 51.98 %)	42.7%
Between 25 and 34	24.56 % (21.71 – 27.41 %)	38.6%
Between 35 and 44	8.33 % (6.48 – 10.18 %)	11.6%
Between 45 and 54	6.80 % (5.11 – 8.49 %)	4.1%
Between 55 and 64	2.08 % (1.1 – 3.06 %)	0.5%
More than 65	0.33 % (0 – 0.76 %)	0.3%
Individuals Geo-location[1]		
Spain	31.25 % (28.19 – 34.31 %)	22.14%
Mexico	15.90 % (13.47 – 18.33 %)	21.46%
Argentina	9.54 % (7.58 – 11.5 %)	10.71%
Colombia	8.99 % (7.08 – 10.9 %)	9.42%
Chile	8.22 % (6.38 – 10.05 %)	7.84%
Peru	6.14 % (4.52 – 7.75 %)	8.74%
Ecuador	3.40 % (2.17 – 4.63 %)	4.39%
Venezuela	3.07 % (1.9 – 4.24 %)	1.58%
Bolivia	2.19 % (1.18 – 3.19 %)	2.49%
Guatemala	1.86 % (0.93 – 2.79 %)	1.33%
Others	9.44 % (7.49 – 11.39 %)	9.90%

[1] Geo-location data for views during July 2020 is shown at population column

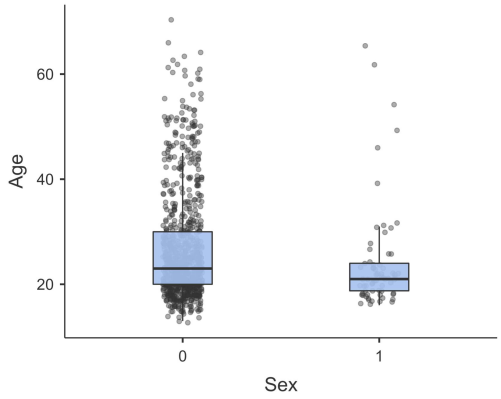

FIGURE 1. Sex vs age boxplot (N = 912).

interval, which means that this group was clearly willing to participate. It is also interesting to highlight that most electrical engineers are within their early professional life.

Finally, considering individuals geo-location, most sample proportions are inside the defined confidence intervals excepting Spain, which is overrepresented, and Mexico, which is underrepresented. The reason for this could be that, when the survey was conducted, the channel was temporarily more devoted to the Spanish public considering the whole group of subscribers due to specific strategies to integrate new videos in Spanish universities. In any case, when a heat map of survey participants' geo-location is presented, as in Fig. 3, it is clear that the channel public is mainly Latin American.

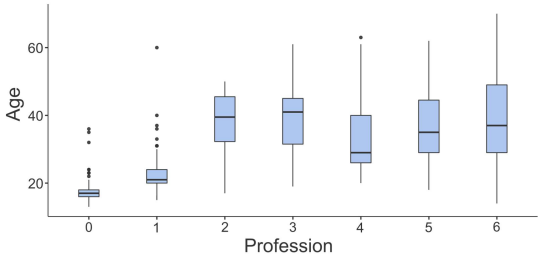

FIGURE 2. Profession vs age boxplot (N = 912). 0: Pre-university students; 1: University students; 2: Pre-university teachers; 3: University teachers; 4: Professionals rlectrical engineering sector; 5: Professionals in other engineering sector (non-electrical); 6: Others.

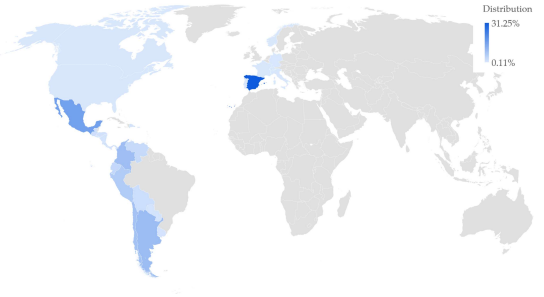

FIGURE 3. Heat map of survey participants' geo-location.

Statistical analysis shown in the Results section has been performed using the software Jamovi [46], considering a confidence level of 95% in all cases. To evaluate potential correlations between qualitative variables, chi-square tests have been used.

D. VALIDITY AND RELIABILITY

In order to validate the reliability of this questionnaire as a suitable data collecting instrument, Cronbach's alpha method was implemented obtaining a coefficient of 0.76. This score is considered as adequate according to authors such as Nunnally [47], who states that, for early stages of a research, a value of 0.5 or 0.6 would be sufficient. Other authors, such as Huh *et al.* [48] consider that reliability value in an exploratory research should be equal or higher than 0.6. Therefore, the survey used as instrument in this article counts on a high reliability rate.

After conducting and validating the questionnaire as our data acquisition instrument, Bartlett's test of sphericity and Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy were studied to allow the posterior performance of an exploratory factorial analysis. Results showed a χ^2 (153) = 2315.3 ($p < 0.001$), and a KMO measure of 0.850, confirming the adequacy of our questionnaire for the performance of a factorial analysis.

Five factors have been identified to explain at least 50% of variance. Accordingly, questions are organized in those five main categories, presented hereafter sorted by their contribution to the objectives of this study:

1) Assessment on channel use preferences.
   - Channel use for non-educative purpose (Q4, Q5, Q10 and Q12).
   - Fan phenomena (immediacy) (Q1).
2) Assessment on channel contents and format adequacy.
   - Content adequacy to solve problems or satisfy topics of interest (Q2, Q3, Q6, Q9 and Q11).
   - Audiovisual format adequacy and communicative style (Q7, Q8, Q13, Q14 and Q15).
3) Perception on educational video integration (Q16, Q17 and Q18).

E. CONFIDENTIALITY

All the answers to the questionnaire were completely anonymous. Additionally, all respondents gave informed consent for the scientific use of the data gathered.

IV. RESULTS

This section presents the results obtained through the conducted survey, organized by subsections as per the objectives of this study. A quantitative analysis of Likert scale in each question of the survey has been performed. Results can be found at Table 3. Additionally, comparative analyses have been performed through chi-square tests, unveiling useful information about the descriptors defined in the questionnaire. Results from chi-squared evaluations can be found at Table 4.

A. ASSESSMENT ON CHANNEL USE PREFERENCES

As presented in Table 3, descriptors for channel use in non-educative purposes (Q4, Q5, Q10 and Q12) show a high frequency of 'agree' and 'strongly agree' answers. The use related to stay updated in news on the sector has suffered of more 'neutral' answers than the other questions. On the other hand, the entertainment use of the channel shows a remarkable 87.2% positive answers, leading to a mean score of 4.46 within the Likert scale.

Though pedagogical use of the channel seems to be less frequent than entertainment use, a high tendency to use the channel for educational purposes can still be found, as shown by the 72.7% positive answers. This finding confirms that the channel is also widely implemented with educational purpose, in consonance with our research question. When comparing users' profession with the frequency of educational use (ID6), chi-squared tests show significant correlation for a 95% confidence level ($p = 0.046$), though evidence backing up this correlation is not as strong as the ones found in previous descriptors comparisons shown in Table 4. The use of the channel in educative contexts is more associated with pre-university teachers, where 80.8% answered positively. Moreover, university students and professionals in electrical engineering sector tend to use the channel for learning purposes with respective values of 73.3% and 78.9%.

After chi-squared evaluations, shown in Table 4, no significant correlation ($p = 0.087$) has been found between educational use of the channel and the opinion on rigor parameter (ID1). However, a strong correlation ($p < 0.001$) is found for entertainment use and rigor (ID2). Regarding videos currentness, results show a significant correlation ($p < 0.001$) with both educational (ID3) and entertainment use (ID4).

Another interesting behavior of non-educational use of the channel is the fan phenomena, which in certain sense could be evaluated through the immediacy of users' reaction to new contents on the channel (Q1). Most students reported watching both recently published videos (Q1) and old channel's videos (Q2). However, there are more quantity of users that tend to watch old videos with higher frequency than

TABLE 3. Questionnaire identifiers (ID), sample (N), and Likert scale frequencies (%), mean scores and standard deviations (SD).

ID	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	SD
Q1	912	3.2	9.9	26.8	32.5	27.7	3.72	1.07
Q2	908	1.2	5.5	15.7	31.7	45.8	4.15	0.96
Q3	905	5.9	8.5	12.9	26.7	46.0	3.98	1.21
Q4	907	0.7	2.3	9.8	24.9	62.3	4.46	0.815
Q5	908	5.5	8.6	21.6	27.4	36.9	3.82	1.18
Q6	911	0.3	1.6	15.6	48.3	34.1	4.14	0.757
Q7	909	0.2	0.6	3.6	29.7	65.9	4.61	0.609
Q8	910	0.0	0.8	6.8	34.0	58.5	4.5	0.658
Q9	907	0.0	1.3	7.2	31.8	59.8	4.5	0.688
Q10	896	1.5	2.5	14.4	34.5	47.2	4.24	0.889
Q11	905	0.2	0.7	5.5	28.4	65.2	4.58	0.649
Q12	897	0.0	0.3	5.8	24.0	69.9	4.63	0.607
Q13	908	0.1	1.7	9.8	28.6	59.8	4.46	0.747
Q14	909	0.1	0.9	7.4	27.0	64.7	4.55	0.679
Q15	895	0.0	0.4	3.0	18.4	78.1	4.74	0.528
Q16	858	3.7	10.5	26.0	27.7	32.1	3.74	1.13
Q17	849	1.1	1.9	11.9	25.2	60.0	4.41	0.849
Q18	862	24.1	26.0	24.2	11.3	14.4	2.66	1.34

TABLE 4. Comparative χ^2 tests between key descriptors of the questionnaire.

	ID1 Q3 vs Q10	ID2 Q4 vs Q10	ID3 Q3 vs Q12	ID4 Q4 vs Q12	ID5 Q4 vs Q12
N	890	893	891	893	901
χ^2	24.1	64.4	41.9	60.1	83.1
p	0.087	<0.001	<0.001	<0.001	<0.001

	ID6 Prof. vs Q3	ID7 Q3 vs Q9	ID8 Q3 vs Q11	ID9 Q7 vs Q11	ID10 Q9 vs Q11
N	905	900	900	904	901
χ^2	36.8	56.8	97.8	218	256
p	0.046	<0.001	<0.001	<0.001	<0.001

	ID11 Q14 vs Q11	ID12 Q3 vs Q15	ID13 Prof. vs Q18
N	904	889	862
χ^2	134	74.9	39.4
p	<0.001	<0.001	0.025

those published at the same week, with respective 'strongly agree' frequencies of 45.8% for old videos and 27.7% for new ones. These indicators might unveil the idea that *Sígueme la Corriente* covers more a utility need rather than a fan-based use, which may be also in consonance with educational applications.

B. ASSESSMENT ON CHANNEL CONTENTS AND FORMAT ADEQUACY

When evaluating content adequacy to solve problems or interests (Q2, Q3, Q6, Q9 and Q11), results show interesting information. As shown in Table 3, there is a high quantity of users that resort to old videos, with a 77.5% of positive answers. Comparative results in Table 4 show that there is strong evidence suggesting significant correlation ($p < 0.001$) between entertainment use of the channel and a predominant use of old published videos (ID5), as means to satisfy specific topics that the user is searching for.

As per the capability of *Sígueme la Corriente* to generate interest in its audience, almost all participants agree that the selection of topics matches their interests, with an 82.4% of positive answers frequency. Additionally, almost all users (91.6%) believe that the technical level is adequate to ensure good concept comprehension, concluding with a mean 4.58 score that the channel's contents are helpful to understand concepts the audience is interested in.

Comparative analysis proves the dependance of didactic use of the channel with respect to the perception that the videos have a proper technical level (ID7), with significant results ($p < 0.001$). Finally, there is also significant correlation ($p < 0.001$) among the educative use of the channel and the opinion that the channels' contents are helpful to understand interesting topics for each individual (ID8).

As explained in Literature Review, audiovisual format adequacy and communicative style (Q7, Q8, Q13, Q14 and Q15) are also relevant descriptors when analyzing the suitability of videos for educational purposes. Referring to those descriptors, parameters such as engaging explanations, rhythm, video duration, and audiovisual resources used for the video creation, are of particular importance.

Results show general agreement in the perception that the presenter communication abilities are able to make contents both attractive and interesting, with a frequency of 95.6% of positive responses to the Likert scale. Additionally, there is a 92.5% positive response to the belief that the rhythm of videos is adequate to ensure good concept understanding. Concerning format adequacy, video's duration is considered adequate by most participants, with 88.4% positive responses, as well as the selection of images and animations to help concept comprehension, achieving 91.7% positive feedback.

Chi-squared tests ID9, ID10 and ID11 in Table 4 also show significant correlation ($p < 0.001$) between the successful educational use of videos and format aspects such as expressive abilities, technical level, and the artistic expression (defined in terms of audiovisual resources adequacy). These findings are in direct connection with our research question regarding the features that make *Sígueme la Corriente*'s videos to be perceived as suitable for educational use.

Because of users' perception on abovementioned descriptors, there is an extended belief that didactic videos could be useful to enhance education quality, with 96.5% positive responses and a mean score of 4.74. Additionally, comparative chi-squared test shows significant correlation ($p < 0.001$) between those who use the channel for educational purpose and the perception that didactic videos could enhance education quality (ID12).

C. PERCEPTION ON VIDEOS INTEGRATION IN AN EDUCATIONAL CONTEXT

As per user opinion on the integration of videos as educational tool (Q16, Q17 and Q18), most users think that it would be useful to provide teachers with competences for the creation of their own videos, with 85.2% positive response. However, less users consider that classrooms are well equipped for the projection of videos, with 26% responses remaining neutral.

On the other hand, most answers remain negative or neutral in the perception that didactic videos could fully substitute assistance-based education. Chi-squared analysis shows correlation for a 95% confidence level ($p = 0.025$) when considering if profession is significant on the perception that didactic videos could be a possible substitute for presence in education (ID13). On one hand, university students showed tendency to disagree with the affirmation, with 50.3% answering 'disagree' or 'strongly disagree' versus the 24.3% that answered 'agree' or 'strongly agree'. On the other hand, results show that university teachers seem to think otherwise, as 60% answered 'agree' versus a 30% that answered 'disagree' or 'strongly disagree'. However, this finding might be affected by a small sample of university teachers, as stated in 'Limitations' subsection.

V. DISCUSSION, LIMITATIONS AND FUTURE WORKS

A. CHANNEL POTENTIAL EDUCATIONAL USE THROUGH ITS AUDIENCE CHARACTERIZATION

Findings support the initial hypothesis that a YouTube informal dissemination channel such as *Sígueme la Corriente*, which was created and developed for entertainment purposes, is also having a side use as an educational aid. Audience perception is very positive towards its educational value and adequacy.

The main channel use preferences are entertainment and education, with respective 87.2% and 72.7% positive use frequency. When evaluating profession distribution among users, the main groups that count on the channel for educational purposes are pre-university teachers, university students and junior electrical engineers.

Though didactic use of the channel was highly rated in questionnaire results, it is still under entertainment use (as shown in results), which can be explained by the fact that the channel's contents has not been developed to consider such pedagogical use. The fact that YouTube is mainly

an entertainment platform was acknowledged by Lee and Lehto [34], addressing it as a challenge for a widely recognition of the educational value of the platform. However, educational use of *Sígueme la Corriente* can still be seen as high for a YouTube informal dissemination channel originated without the aim of covering didactic uses.

Regarding the perception on channel's contents rigorousness, a strong correlation has been detected between entertainment use and the perception of rigor as an important parameter. These results lead us to infer that, for the channel's audience, rigor is not as characteristic from the utility perspective as from the entertainment perspective. This is also coherent with results from the factorial analysis, exposed in 'Methodology' section.

Referring to channel users' characteristics, it is also interesting to remark the fact that, though gender distribution of the channel's user is remarkably asymmetrical, women are mostly young (as shown in Fig. 1). This appreciation is consistent with results shown by Saurabh and Gautam [49], in whose analysis of an information technology YouTube channel there were 20-30% women users, and they were mainly distributed through 13 and 24 years old. These data might back up the hypothesis that young women are becoming increasingly more interested in engineering and technology.

Besides channel use tendencies, there are also several aspects worth highlighting related to content and format adequacy. When evaluating the audience perception on such descriptors, a remarkably positive perception can be found from survey participants on production quality, video length, explanation rhythm, accuracy and completeness, narrator confidence, and engaging communication style. These are the main characteristics of evaluation rubrics suggested by several authors [40]–[42] to evaluate the suitability of certain videos as teaching aid for specific concepts that might need visual reinforcement. Those descriptors are also in consonance with the Lee and Lehto's proposal of extended TAM for user acceptance of YouTube procedural learning [34].

Additionally, results show correlation between those who use the channel for educational purposes and the perception that its technical level is adequate for their needs, which can be associated with the conclusion that the channel's contents are perceived as adequate for pedagogical integration.

When evaluating videos usefulness to satisfy the understanding of topics of interest, we found a remarkably positive reaction with a 4.58 score (in a scale from 1 to 5). This result is in consonance with the 4.15 score obtained by D'Aquila *et al.* [37] for the same question asked in accounting video-aided lessons. Also Wells *et al.* [15] asked their students about video tutorials usefulness to help learning their unit material, obtaining frequencies of 46% and 45% to 'always' and 'often', respectively. These results serve as practical demonstrations of video potential to facilitate comprehension of abstract complex concepts characteristically found in STEM education.

Furthermore, the perception on engagement as evaluating parameter for the presenter communication style is highly rated by participants, with a score of 4.61. This idea has also been highlighted by Gil-Quintana *et al.* [33], with results showing youtubers as the preferred academic reference for students due to their communicative skills. Moreover, Shoufan findings [21] also show that the main feedback from students when integrating videos as part of the learning experience are focused on an increase of interest and motivation, which directly results in an engagement enhancement. Results collected by Jackman and Roberts [11] also highlights illustrations, explanations, and examples as the main areas of recall when referring to long-term learning and better retention, metrics of which *Sígueme la Corriente* users tend to show a very positive perception (as reflected in answers to Q7, Q11 and Q14).

Additionally, drawings and animations are frequently used in the channels' videos to illustrate engineering concepts. These features might also be used by students when approaching such concepts. Aligned with this Wu *et al.* [12] described how drawing prompts, both driven by classes and video, might constitute a useful tool to increase students' use of drawing as a problem-solving strategy. This practice, as quantified in their study case, can enhance cognitive engagement and performance in an engineering active learning environment.

Our results have also shown strong correlation in users' perception between video format aspects (defined by communicative abilities, technical level, and artistic integration to illustrate technical concepts) and pedagogical aspects. These findings confirm results from Romero-Tena *et al.* [42], where significant correlation was exposed for the same descriptors. The implication of this correlation is also consistent with previously detailed results, as it also describes how the content and format adequacy of videos is a relevant aspect for user's perception of their educational value.

Finally, when evaluating the audience opinion on the effects of pedagogical video integration in education, most users think that teachers should be provided with more competences on video creation for their lectures. This belief is also clearly related to UN's education quality Sustainable Development Goal (SDG) indicator 4.4.1, which goal is to substantially increase the number of young and adults with relevant ICT skills. The overall initiative in which *Sígueme la Corriente* is immersed aims to contribute to this goal by developing specific educational contents framed in technology integration models such as CoI and ICT-TPACK. Additionally, SDG 4.7.1. goal is implicitly included as part of our project contribution, as it relies on ensuring that all learners acquire the knowledge and skills needed to promote sustainable development. *Sígueme la Corriente* specifically addresses such sustainable development promotion in all its videos, as it is a channel particularly specialized in energy and sustainability.

In relation to possible future implementation of educational videos, there is no agreement regarding the idea that

didactic videos could completely substitute assistance-based education. Instead, whereas there is only a 25.7% of positive answers, a frequency of 50.1% answered negatively to this descriptor. The remaining 24.2% maintained a neutral perspective. Results for university student perception show a divided opinion where 50.3% were inclined to reject this idea of fully substituting classroom teaching by media resources. It is a percentage accurately backing up previous findings by D'Aquila [37] where 54.14% of students prefer live classes than video format as complete substitution. These findings are also consistent with research from Muthuprasad *et al.* [4], where more than 70% of students answered negatively or neutrally to each one of the following statements: (1) Online courses were preferable than classroom learning, (2) Online classes were more helpful to comprehend course materials, and (3) Online environment makes communication with the instructor easier.

As shown by results from Gupta and Sengupta [50], students find desirable to integrate YouTube webinars as substitution of some presential lessons due to its greater accessibility and the option to attend from any location. However, factors such as technology availability or the need from face-to-face interaction are still valued.

This partial rejection to video format as full replacement on traditional assistance-based education, together with overall previous evaluation on user perception of videos benefits, suggests students' recognition and preference for videos as a complementary educational tool, which could not only help understanding exposed knowledge from specific subjects but also encourage an increase of motivation and interest in its contents. Previous research driven by Castro-Sánchez and Chirino-Alemán [32] also shows evidence that teachers consider ICT tools as helpful supporting resources for attendance-based lectures, instead of substitutes that would acquire the main role in the whole pedagogical process. As found by Pattier [29], three out of four teachers are satisfied with the use of video material as pedagogical aid, also stating that most of those that sowed rejection were based on the lack of appropriate technological resources in their educational centers. Research driven by Lo & Hew [20] show how the use of this kind of instructional videos in flipped classroom strategies has demonstrated to have a positive effect over traditional lecture-based learning, enabling students' self-paced learning and awareness of the practical applications of the studied concepts. On the other hand, Wells *et al.* [15] research has shown video tutorials as the most helpful resource for students, with a punctuation of 84%, over other resources such as lecture slides, assignments or even lectures themselves, suggesting that their students might not be opposed to the idea of video material use as substitute of classroom lectures. More research should be performed aiming to confirm the significance of these differences.

To conclude, there is an overall positive evaluation on the perception of *Sígueme la Corriente* users on its adequacy as an educational tool. Results show how the vast majority of the channel's users believe that didactic videos such as presented ones could help enhancing the quality of education, with 96.5% positive responses. Exposed findings back up the idea that informal scientific dissemination audiovisual resources might be serving both entertainment and educational purposes, and this conclusion unveils the need to implement on such dissemination channels formal strategies to successfully develop educational contents. This kind of resources could also contribute creating connections between technical subjects in electrical engineering that would otherwise be perceived as individual and unrelated, as pointed out by Maciejewski *et al.* [7]. Videos as the ones provided by *Sígueme la Corriente* could also be useful to provide pre-university students with more information about electrical engineering, as well as first-hand prospects about the professional application of the degree and job stability and promotion. Therefore, as described by Tayebi *et al.* [17], such use of the channel would be directly influencing some of the main parameters affecting dropout rates in engineering studies.

However, more research is still needed on real case studios for the implementation of successful methodologies that could serve as guidelines for both creators and lecturers on how to integrate such audiovisual resources in educative contexts. This aspect is also highlighted by Pattier [29], concluding teachers difficulties on finding videos that adapt to their academic needs. Fyfield work [51] also concludes that the use of videos in classroom does not necessarily imply a change for traditional classroom interactions, as they are often used to replace the teacher's direct instruction or as static source like textbooks. In this sense, more innovative video integration strategies could potentially be developed for a more successful use of YouTube videos as pedagogical aid.

Such integration strategies should be based on technology integration models in educational environments such as previously mentioned CoI or ICT-TPACK. 'Future Works' subsection states the proposed objectives to continue developing this research line addressing those needs.

B. LIMITATIONS

There are several limitations in this study that should be highlighted. Though the channel audience is fairly well represented, there are certain groups that are not perfectly characterized (as exposed in 'Methodology' section), such as group age between 25 and 34. It is also noticeable the underrepresentation of university and pre-university teachers (as mentioned in 'Sample Description' subsection). Finally, the fact that this study is focused in a specific channel could affect extrapolating conclusions to the overall fitness of scientific dissemination YouTube channels. May this study serve as a first step to develop further evaluations in collaboration with other content creators from similar dissemination channels.

C. FUTURE WORKS

This study represents the beginning of a research line intended to contribute to the current literature in video integration as an educational aid in STEM disciplines, and how

available scientific dissemination resources might be adequate for those means.

After analyzing the adequacy of *Sígueme la Corriente* to be used as a teaching aid resource, a new section will be developed in the channel where specific needs of Electrical Engineering degrees could be addressed. Concept maps [52], [53] are deemed as a potentially useful tool to detect those key areas that would need to be reinforced and, thus, they will be further developed. This approach would be designed with the objective of reinforcing conceptual connections between subjects which, according to Maciejewski *et al.* [7], is a current need in electrical engineering. Practical case studies should be performed to evaluate the effects of those videos' integration in a real classroom environment. Pursuing both objectives, CoI and ICT-TPACK models could serve as conceptual framework.

Additionally, in an attempt to overcome one of the main limitations of this study, more evaluations will be performed in similar dissemination channels of other disciplines in order to further confirm the findings of this article and extrapolate them to other fields of study.

VI. CONCLUSION

Two main research questions have served as central guide for this study: are YouTube dissemination videos being integrated in electrical engineering education? In that case, what are their most valued features for such pedagogical use?

Sígueme la Corriente channel has been used as case study, and the following objectives have been set as methodology to answer the previous questions:

(1) To identify whether *Sígueme la Corriente* might be having a side-educational use (as inferred from received comments and source views statistics).
(2) To evaluate its audience perception on metrics considered in literature as essential for educational videos (format and content adequacy).
(3) To receive hints about the audience's perception on the effects of educational video integration as pedagogical aids.

As developed in 'Literature Review' section, there are several benefits from the use of videos as complementary pedagogical aids in higher education, though it is not always easy for lecturers to find time, knowledge, and resources to elaborate their own videos in an adequate format. For this purpose, YouTube can be a valuable source considering the high number of available videos on many specialized topics. The key challenge lies on lecturers being able to identify content and format adequacy of those videos. Additionally, from the creator's perspective, YouTube dissemination channels generally lack of specific pedagogical strategies backing up their content creation, and this might arise doubts on their actual educational suitability. If such unintentional educational use is correctly identified, it could serve as trigger for the implementation of educational models that could successfully lead the development strategy of subsequent videos.

Results obtained in our case study show how this is the case for *Sígueme la Corriente*, which already has a high rate of educational use that confirms our first research question. The main groups using the channel for this purpose are pre-university teachers, university students and junior electrical engineers. We detect slight differences with Lee and Lehto [34] perception that the educational value of YouTube is not appreciated due to its wide social recognition as an entertainment site. In this regard, *Sígueme la Corriente* users claim to take profit of the channel for educational purposes with a positive frequency of 72.7% even though this is not one of the objectives to which its contents were conceived.

Audiovisual format used in this channel, together with its contents, are remarkably rated as positive by its audience. Users perceive that the channels' videos are useful for understanding topics of interest, as shown by a 93.6% frequency on positive responses. This is in consonance with results from both D'Aquila *et al.* [37] and Wells *et al.* [15]. In this regard, there is significant correlation between that belief and the educational use of the channel. Additionally, the presenter's communicative style is rated as attractive and interesting, which contributes to overall channel engagement rates. Our results for these parameters are aligned with the ones obtained Gil Quintana *et al.* [33]. Therefore, as a response to our second research question, the most valued features for the educational use of the channel are its engaging explanations, the rhythm and duration of its videos, their technical level, and their artistic expression.

Results suggest students' preference for videos as a complementary resource to enhance understanding of topics studied in lectures. In consonance with D'Aquila *et al.* [37] and Muthuprasad *et al.* [4], we find no clear tendency, among those who use the channel for didactic purpose, to believe that videos could be a potential full substitute for assistance-based education. We appreciate differences in this regard with Wells *et al.* [15], whose results show that video resources are perceived by their students as more helpful than lectures.

However, *Sígueme la Corriente* users recognize videos as a successful resource to enhance their overall education experience, that could be potentially considered as an adequate complementary tool both for distance and face to face education.

To sum up, the implications of previous findings are positive when considering the potential educational use of an existing YouTube dissemination channel. Such resources might also derive in a significant raise of students' interest in engineering jobs, as reported by Colston *et al.* [16]. *Sígueme la Corriente* directly approaches that objective, providing teachers and students with easy-to-follow engineering explanations from a professional in the electrical engineering field.

However, though parameters such as audiovisual format, communicative style, and technical level seem to be perceived as adequate, there is still need to continue developing tools that may serve as guidelines to enhance video integration as educational tool from the perspective of content creators, lecturers, and students. Those strategies should be backed up

by state-of-the-art educational models such as CoI and ICT-TPACK, as previously cited in this article. Our future research will integrate specifically developed educational videos in a particular electrical engineering subject, to evaluate the perception of university students when such contents are presented as part of their study material.

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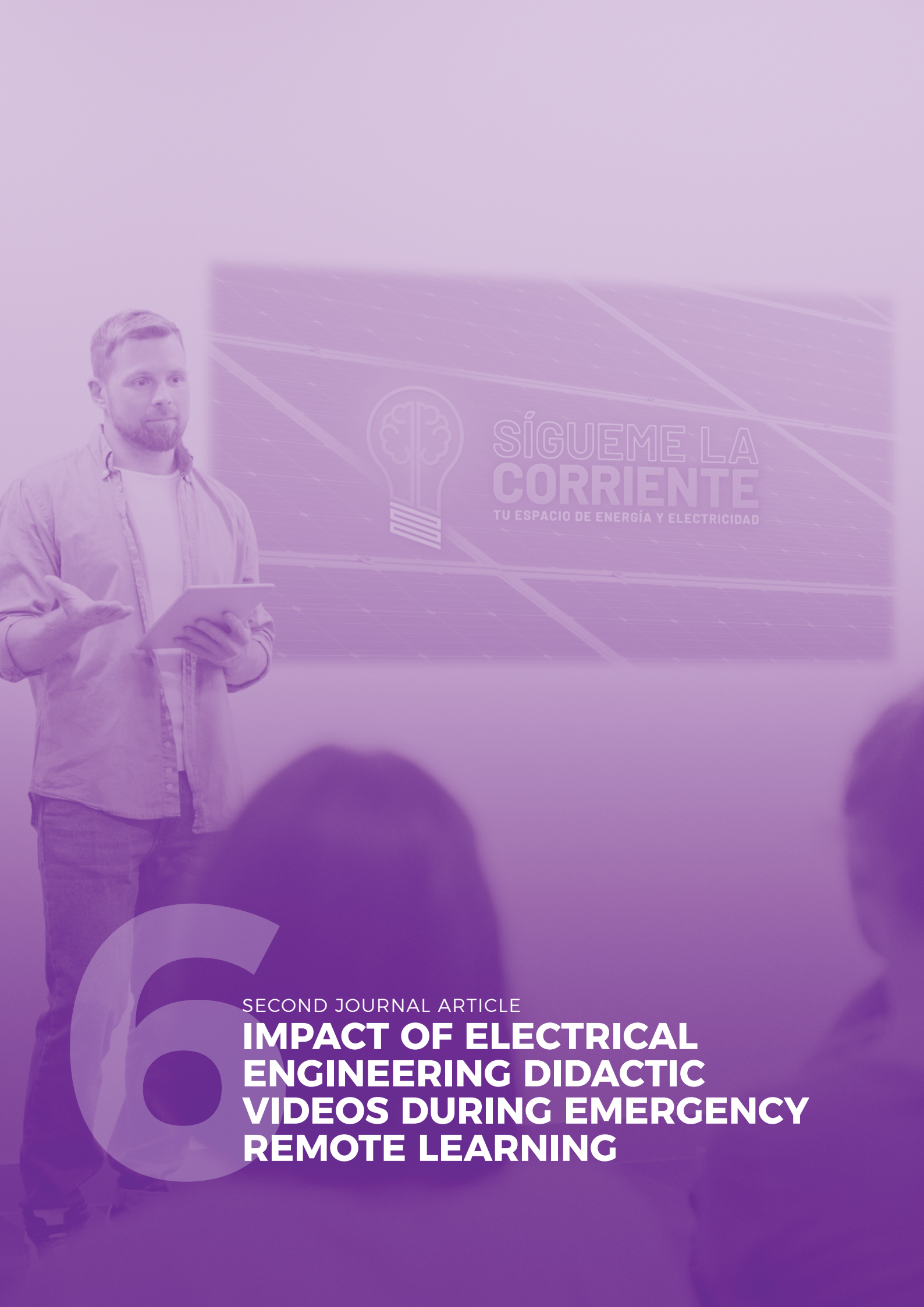
Since 1996, he has been a full-time Professor with the Department of Electrical Engineering, BarcelonaTech. His research interests include high voltage and power plants, allometric scaling, and complexity in power networks.



6

SECOND JOURNAL ARTICLE

IMPACT OF ELECTRICAL ENGINEERING DIDACTIC VIDEOS DURING EMERGENCY REMOTE LEARNING

6. Second journal article: Impact of electrical engineering didactic videos during emergency remote learning

6.1 Article's Main Information

- **Journal:** IEEE Access (Volume: 11).
- **Section:** IEEE Education Society Section.
- **Indexed in:** IEEE Access is included in the Clarivate Analytics Web of Science (WoS - JCR), which includes Science Citations Index Expanded, Journal Citation Report/Science Edition, and Current Contents Engineering, Computing and Technology Edition. IEEE Access has an impact factor of 3.9 (Q2), an Eigenfactor of 0.32872, a five-year impact factor of 4.1, and an immediacy index of 0.7 (per 2022 JCR). This journal is also included in Scopus, with a CiteScore of 9 (per 2022 Scopus) and a Scimago Journal Rank of 0.96 (Q1) (per 2023 SJR). Moreover, IEEE Access is also indexed by Inspec, Ei Compendex, and EBSCOhost. It is also listed in the Directory of Open Access Journals (DOAJ).
- **Publisher:** Institute of Electrical and Electronics Engineers (IEEE).
- **Pages:** 19622 - 19634.
- **Date of publication:** 23 February 2023.
- **ISSN:** 2169-3536.
- **DOI:** 10.1109/ACCESS.2023.3248299.
- **Video abstract:** this article has a video abstract available through its online publication interface at IEEE Xplore. Access available at: https://doi.org/10.1109/ACCESS.2023.3248299.

Cite this article as: R. Lijo, E. Quevedo, J. J. Castro and R. Horta, "Impact of Electrical Engineering Didactic Videos During Emergency Remote Learning," in IEEE Access, vol. 11, pp. 19622-19634, 2023, doi: 10.1109/ACCESS.2023.3248299.

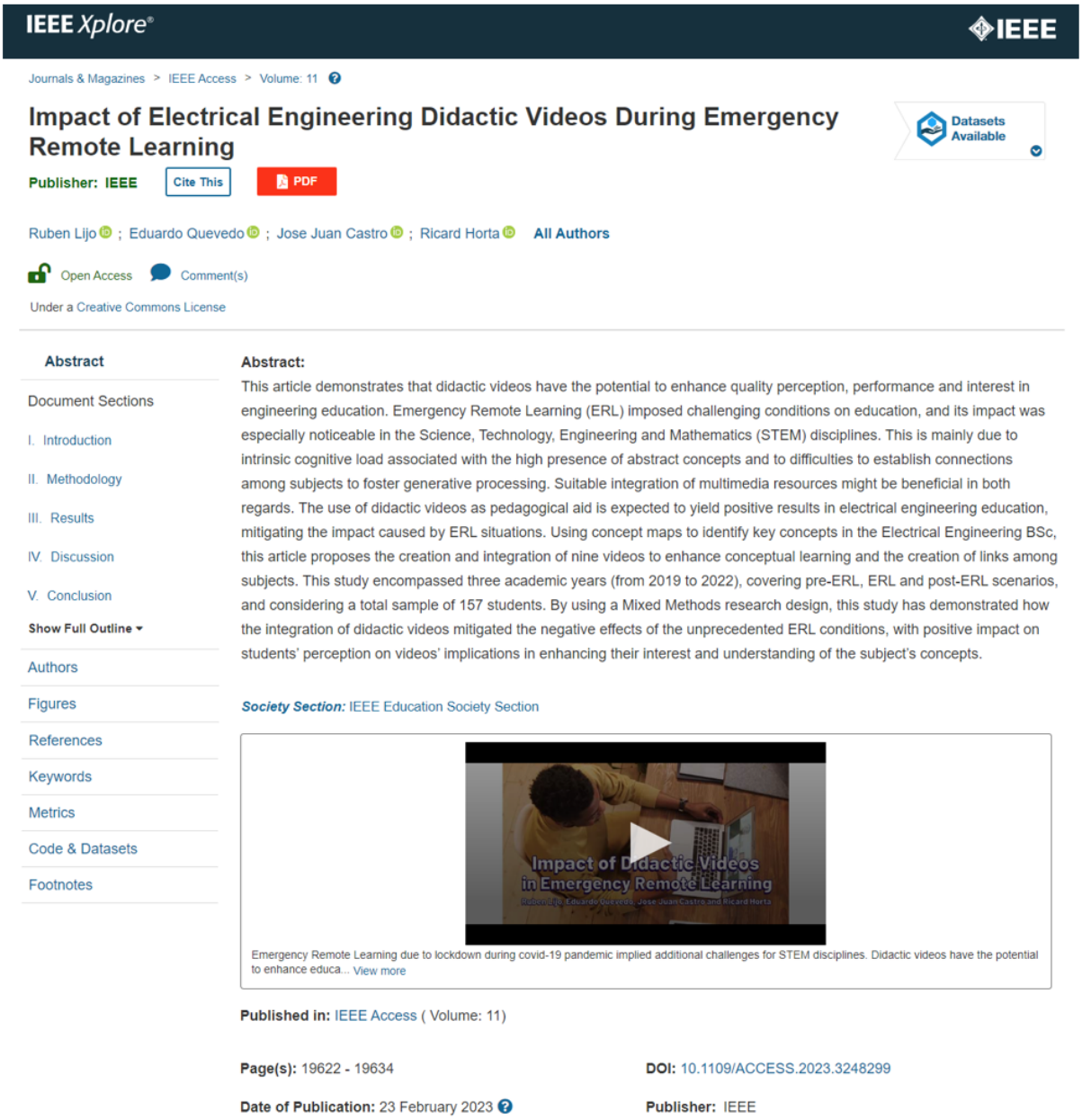


Figure 26. Online publication of the article 2 at IEEE Xplore.

6.2 Embedded Article

IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

IEEE EDUCATION SOCIETY SECTION

Received 6 February 2023, accepted 21 February 2023, date of publication 23 February 2023, date of current version 1 March 2023.

Digital Object Identifier 10.1109/ACCESS.2023.3248299

RESEARCH ARTICLE

Impact of Electrical Engineering Didactic Videos During Emergency Remote Learning

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ABSTRACT This article demonstrates that didactic videos have the potential to enhance quality perception, performance and interest in engineering education. Emergency Remote Learning (ERL) imposed challenging conditions on education, and its impact was especially noticeable in the Science, Technology, Engineering and Mathematics (STEM) disciplines. This is mainly due to intrinsic cognitive load associated with the high presence of abstract concepts and to difficulties to establish connections among subjects to foster generative processing. Suitable integration of multimedia resources might be beneficial in both regards. The use of didactic videos as pedagogical aid is expected to yield positive results in electrical engineering education, mitigating the impact caused by ERL situations. Using concept maps to identify key concepts in the Electrical Engineering BSc, this article proposes the creation and integration of nine videos to enhance conceptual learning and the creation of links among subjects. This study encompassed three academic years (from 2019 to 2022), covering pre-ERL, ERL and post-ERL scenarios, and considering a total sample of 157 students. By using a Mixed Methods research design, this study has demonstrated how the integration of didactic videos mitigated the negative effects of the unprecedented ERL conditions, with positive impact on students' perception on videos' implications in enhancing their interest and understanding of the subject's concepts.

INDEX TERMS Conceptual learning, distance learning, educational technology, electrical engineering education, emergency remote learning, STEM, videos, YouTube.

I. INTRODUCTION

The Emergency Remote Learning (ERL) entailed by the covid-19 lockdown implied additional challenges for Science, Technology, Engineering and Mathematics (STEM) disciplines, such as concentration issues, reduced interaction, or non-structured pedagogical methods [1]. In this unprecedented situation, Information and Communication Technologies (ICT) were key to ensure the continuity of education, though the improvised nature of ERL prevented the creation of structured designs for a complete online learning experience [1], [2], [3], [4].

Audiovisual resources have proven to be an effective pedagogical tool, and their benefits are directly related to some of the shortcomings produced by ERL. The Cognitive Theory of Multimedia Learning (CTML), based on the Cognitive Load Theory (CLT), offers insights on the impact of multimedia on processing capacity [5], [6], [7]. Extraneous cognitive overload produced by the improvised instructional approach during ERL could be reduced with the use of

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

suitable didactic multimedia that allow students to review and to reinforce the explained concepts with well-structured explanations and promote self-paced learning. Essential cognitive load, related to the processing of information to create mental representations in the working memory, can also be reduced with videos given that they increase the number of sensory channels involved in the learning process (visual and auditory).

Moreover, generative processing for the organization of received information and its integration with previous knowledge could be fostered with an organized structure of videos that escalate in level, as well as reinforcing the links among subjects within the degree. This is a specific

challenge of engineering education, where additional difficulties are found for the understanding of connections between subjects, usually delivered in a silo-like fashion [8], [9], [10]. This may lead to a reduction in motivation and confidence, particularly in abstract disciplines, which could be mitigated with an adequate integration of multimedia resources within active learning methodologies, that could also improve academic performance [10], [11], [12], [13], [14], [15], [16], [17].

However, several authors also highlight teachers' difficulties on finding suitable videos for their academic needs [15], [18], [19], [20], as well as students' problems to choose videos for complementary self-directed learning [21]. Additionally, other authors highlight teachers' need to enhance their pedagogical knowledge, as specialization in their STEM discipline might not be enough for a suitable implementation of video-aided learning strategies [17], [22]. Technological Pedagogical Content Knowledge (TPACK), describes the need for this continuous knowledge improvement of lecturers with a view to the successful integration of ICT in educational environments [23], [24], [25], [26], [27].

This article aims to evaluate the mitigating effects of didactic videos on the impact of ERL on education quality perception, performance, and interest in a real electrical engineering classroom environment. For this purpose, concept maps have been used as a helping tool to highlight significant relations among key ideas in order to develop visual schemes that contribute to identify key topics where the benefits of didactic videos could be optimal not only to reinforce a subject's topics of interest, but also their relationship with other subjects of the degree [28], [29]. This analysis helped to design a specific series of didactic videos that were published in a YouTube channel serving both educational and scientific dissemination purposes, which were subsequently distributed among the students of "Electrical Machines I" of the Electrical Engineering BSc from the School of Industrial, Aerospace and Audiovisual Engineering of Terrassa (*Universitat Politècnica de Catalunya*) [30]. The selected channel is *Sígueme la Corriente* [31], which has been studied in previous exploratory research, and has been found potentially suitable for educational use based on users' perception about key metrics related to content and format adequacy [11], [32]. This research extends through three academic years, and addresses the following research questions with a Mixed Methods approach:

- RQ1: Did ERL produce differences in education quality perception and academic performance?
- RQ2: Did didactic videos contribute to mitigate the impact of ERL from the students' perspective?
- RQ3: Did didactic videos contribute to boost motivation and interest in the subject?

After this initial introduction to video integration as pedagogical aid in STEM disciplines, Section II addresses the research design and methodology followed during this study, including relevant aspects of data collection and analysis. Section III presents the most relevant results from both the quantitative and the qualitative phases of the study, showing the impact of didactic videos in students' perception of education quality, performance and motivation for three academic courses covering pre-ERL, ERL and post-ERL scenarios. Section IV analyzes the implications of this study, as well as its contribution to current literature. Finally, Section V highlights the main conclusions of this article, followed by a summary of its limitations and future research in Section VI.

II. METHODOLOGY

This study focuses on the course "Electrical Machines I" (60 hours) taught in the fifth semester of the Electrical Engineering BSc from the School of Industrial, Aerospace and Audiovisual Engineering of Terrassa (*Universitat Politècnica de Catalunya*) [30]. Using concept maps (see Appendix I), it has been detected that both electromagnetism and 3-phase circuits are key concepts for 32.2% of the subjects that make up the electrical engineering degree. Concept maps have been created using CMapTools [33].

There is a specific organizational challenge at *Universitat Politècnica de Catalunya* regarding these selected areas of knowledge. Both electromagnetism and 3-phase circuits are taught as part of three elementary courses, where students from electrical engineering share classroom with students from other engineering branches, which implies that the overall level of instruction received in relation to these concepts is lower than what could be desired for an electrical engineer. Dealing with such key concepts as common topics for diverse engineering branches may be detrimental to the depth of knowledge about said concepts, thus creating a bottleneck for the subsequent subjects of the degree. One of the first subjects affected by this problem in the degree is "Electrical Machines I".

As means to homogenize the access level in the Electrical Machines I course, and to mitigate some of the negative effects of ERL reported in literature, video-aided reinforcement is proposed as a harmonization strategy, aiming to provide conceptual explanations for students to fill the gaps of previous knowledge and acquire the recommended level in Electromagnetism and 3-Phase Circuits. The objective behind such video-aided harmonization strategy is taking advantage of videos' potential to lower both essential and

extraneous cognitive load, as well as promoting generative processing as explained by CTML. A specific series of 9 scientific dissemination videos was created in *Sígueme la Corriente*, considering key metrics from literature on format and content adequacy as guidelines for their creation, such as explanation quality, audiovisual quality, contents' technical level and rhythm, efficient length, voice and language, or interestingness [11], [19], [34], [35], [36]. As inclusion criteria, such videos would cover the main topics of Electromagnetism and 3-Phase Circuits, considered as core knowledge for electrical engineering degree and to a degree of complexity that allows students to reach an appropriate entry level to Electrical Machines I subject.

Additionally, animations and visual explanations played an important role in each one of the videos as a means to enhance essential processing. Videos were distributed to students through Moodle, and they are also collected and available in two playlists of the channel: Electromagnetism [37] and 3-Phase Circuits [38]. This continuous availability of the videos allowed students to review and reinforce concepts at their own pace, which contributes to reduce the extraneous cognitive overload produced by ERL. The organized structure of created videos, escalating in level from introductory chapters to advanced conceptual explanations, is also aimed at fostering generative processing for the suitable organization of new knowledge, and its integration with previous explanations.

A. DESCRIPTION OF THE APPLIED MIXED METHODS STUDY

This study has been carried out during three academic years, where two groups have been distinguished: a control group with students from the 2019/2020 course (pre-ERL) and two experimental groups with students from 2020/2021 year (ERL) and 2021/2022 year (post-ERL). The control group took the classes following a strictly traditional pedagogic approach, with no use of eLearning methodologies or video-based learning, whereas the experimental groups completed the course following a distance-learning approach with complementary video support, starting with ERL during the covid-19 pandemic and continuing with a more normalized distance learning situation. Both situations of distance learning comprised synchronous classes through videoconference services, which were recorded and made available to students, as well as the use of dissemination videos in Moodle to complement base knowledge. No further change in methodology is considered among selected courses. In all courses, laboratory classes remained presential due to its practical component. Additionally, exams were held on-site at the university, and were composed by three parts: theory exam, problems exam and laboratory exam. Throughout the three courses considered in this study, the subject was taught by the same professor and included the same contents, as well as similar evaluation activities.

This research is based on a mixed methods sequential explanatory design, intended to complement quantitative analysis on education quality perceptions and academic performance with a deeper qualitative analysis of the impact of didactic videos in motivation and mitigation of negative ERL effects.

B. STUDY PHASES AND DATA COLLECTION

Data collection has been structured in three phases, starting with a quantitative approach distributed in two stages (phase 1 and 2) of a quasi-experimental post-test design with control group. This analysis is complemented by a case study qualitative approach (phase 3), to further understand the implications of video in an ERL pedagogical environment. Data collected has been made available online through IEEE DataPort [39].

Phase 1 of this study is intended to evaluate the variation of students' perception on education quality for the duration of the experiment. For this purpose, the distributed questionnaire is based on the validated Students' Evaluations of Educational Quality (SEEQ) survey for higher education [40], which is composed of 32 Likert scaled questions organized in nine factors as shown in Appendix II.

Phase 2 aims to quantify the variation in obtained grades. This evaluation is based on a direct comparison of the final grades report between both experimental groups and the control group.

Phase 3 has been designed to evaluate more deeply how the proposed videos may have affected students' motivation and engagement throughout the course, despite the identified negative effects of ERL. This qualitative assessment has been performed through a structured interview with the objective to better understand and cross-check previous results obtained through the SEEQ survey and academic performance. The interview's structure has been based in tensions deducted from research questions:

- Distance education impact on performance.
- Quantity of videos watched (1-9).
- Type of use of the videos (satisfying curiosity, exam preparation, etc.).
- Impact of videos on motivation and interest in the subject
- Relevance of the content creator's identity (professor vs. professional in the field).
- Implications of proposed videos as teaching complement.

Differentiations per age and sex groups were not considered in this study. On the one hand, the population was composed by students of similar age, between 18 and 20 years old for more than the 95% of cases in all years analyzed, as this is a second-year course in the degree. On the other hand, regarding gender, women were underrepresented as there were 5 women out of 47 (10.63%) students in the pre-ERL year, 5 women out of 44 (11.36%) students in the ERL year, and 4 women out of 66 (6.06%) students in the post-ERL year.

Table 1 shows the sample considered in each phase. For phase 1, according to previous evaluations of reliability, validity and usefulness of the instrument performed by Marsh [41], between 10 to 15 or more students show reliable

TABLE 1. Participants in each phase of the study.

ID	Academic year	Phase 1	Phase 2	Phase 3
Pre-ERL	2019/2020	27	47	N/A
ERL	2020/2021	23	44	14
Post-ERL	2021/2022	35	66	7

results through the SEEQ instrument, which is more than doubled in our study for all cases. Class ratings from a sample smaller than 10% of the population should be interpreted carefully, but this is not the case as we are considering in all cases more than 50% of the population. The sample in phase 2 matches the population, as it comes directly from grades reports, whereas in phase 3 several volunteer students from experimental groups participated in the structured qualitative interviews.

Data collection for phase 1 was carried out immediately after the final examinations of the subject both for ERL and post-ERL. The case of pre-ERL students was singular because they were reached between January and March 2021 in order to gather reference information from pre-ERL scenario. Phase 2 source of information are grades reports, and they were collected immediately after the course was finished in each course. Finally, structured interviews constituting phase 3 lasted two weeks for the ERL course and two days for the post-ERL course.

C. DATA ANALYSIS

The statistical analysis shown in the Results section has been performed using SPSS [42] and Jamovi [43], with a confidence level of 95% in all cases. For phases 1 and 2, normality Shapiro-Wilk test confirms the non-normal distribution of data, so non-parametric Mann-Whitney U tests were performed to compare independent samples.

Additionally, for qualitative analysis of the structured interviews during phase 3, all participations were coded following a deductive process after an initial exploratory evaluation. A final number of 40 codes have been defined within the following 6 categories:

- Learning parameters.
- Learning environment.
- Video benefits.
- Subjective valuation.
- Stakeholders.
- Variation in perception.

Participations were collected in Spanish, and equivalent English terms for codes have been considered as per the concepts commonly used in literature. Cooccurrence analyses have been performed to detect relevant relations among codes, and Sankey diagrams are presented for their graphic representation. ATLAS.ti software [44] has been used for these purposes.

D. CONFIDENTIALITY

All participants in this study gave informed consent for the scientific use of the data gathered. Answers to the SEEQ questionnaire were completely anonymous, and grades reports were anonymized before analysis. In the case of structured interviews, no personal data was registered.

III. RESULTS

This section presents the results obtained throughout the three phases of the study, aiming to evaluate the variations with respect to traditional education as a control group (pre-ERL), to covid-19 imposed distance learning (ERL) and a more normalized experience of online learning (post-ERL). The objective is to find implications from the integration of didactic videos as a mitigating strategy for the negative effects of ERL.

A. PHASE 1: IMPACT OF METHODOLOGY CHANGE IN PERCEPTION OF EDUCATION QUALITY

The 32 questions proposed by the SEEQ survey are structured according to nine different factors, meant to evaluate the different dimensions to which students' perception of education quality is composed of. Such factors are:

- F1 Learning: understanding, interest in the subject and learning outcomes.
- F2 Enthusiasm: professor's dynamism, enthusiasm, energy, and humor.
- F3 Organization: subject's organization and clarity of teaching.
- F4 Group Interaction: how students were encouraged to interact with the rest of the group during synchronous classes.
- F5 Individual rapport: the individual attention that the professor provided to each student.
- F6 Breadth: subjects' contents contextualization and connection with the broader picture of the discipline.
- F7 Exams: suitability of evaluation activities to fairly assess the students' knowledge on the course's contents.
- F8 Assignments: suitability of texts or other homework and laboratory activities for the subjects' objectives.
- F9 Overall: professor and subject overall evaluation.

Figure 1 shows the mean values for all factors during the whole experiment duration. Additionally, detailed results for each question are shown in Appendix II.

During ERL, it is possible to detect a reduction in students' perception about all factors except group interaction. Afterwards, the post-ERL experimental group shows a recovery of mean scores to values similar to those of the control group.

Table 2 shows the statistical significance of the comparison among groups. Comparing pre-ERL with ERL groups, there is significant reduction in the following factors: Learning, Enthusiasm, Individual rapport, Breadth, Exams and Assignments. The fact that students' perception of professor enthusiasm is affected might be particularly relevant when it comes to the professor's ability to stimulate the interest of students in the subject. On the other hand, comparing pre-ERL with post-ERL we only find significant difference in individual rapport factor, mainly due to a change in the perception of the professor's availability for help or advice.

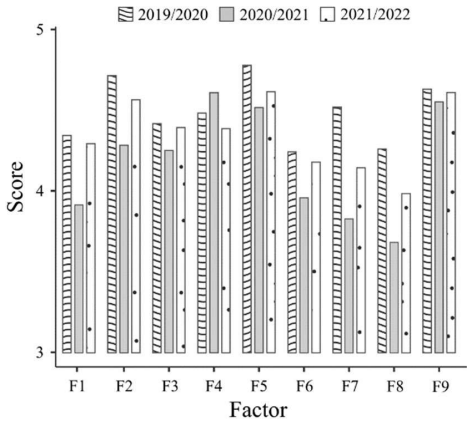

FIGURE 1. Average results per SEEQ survey factors, being F1 Learning, F2 Enthusiasm, F3 Organization, F4 Group Interaction, F5 Individual rapport, F6 Breadth, F7 Exams, F8 Assignments, and F9 Overall.

TABLE 2. Comparison among SEEQ survey factors.

Factors	*p* value		
	Pre-ERL vs ERL	Pre-ERL vs Post-ERL	ERL vs Post-ERL
1. Learning	**0.004**	0.472	**0.019**
2. Enthusiasm	**0.003**	0.283	**0.023**
3. Organization	0.207	0.942	0.238
4. Group interaction	0.469	0.446	0.123
5. Individual rapport	**0.001**	**0.008**	0.371
6. Breadth	**0.045**	0.571	0.112
7. Exams	**0.001**	0.057	0.129
8. Assignments	**0.000**	0.193	0.073
9. Overall	0.173	0.945	0.195

*Mann-Whitney *U* test. Bold values: p<0.05.

The rest of parameters are back to normal possibly due to a more normalized experience with online learning.

When comparing the two experimental groups, a significant increase in the Learning and Enthusiasm factors is found as students and professor grow accustomed to distance learning. There are specific enhancements in students' perception of the understanding of the subject's contents and the engagement with professor's style of presentation.

B. PHASE 2: IMPACT OF METHODOLOGY CHANGE IN ACADEMIC PERFORMANCE

As a means to evaluate the changes in academic performance, grades reports have been analyzed. The pre-ERL group shows a mean final grade of 5.27 (SD 2.36), whereas the experimental ERL and post-ERL groups show, respectively, means of 4.25 (SD 2.47) and 4.90 (SD 2.79). Whereas this evolution might seem similar to the one previously seen for SEEQ in subsection A, the Mann-Whitney *U* test finds no significant difference among years.

However, interesting information emerges when comparing separately each one of the evaluation activities.

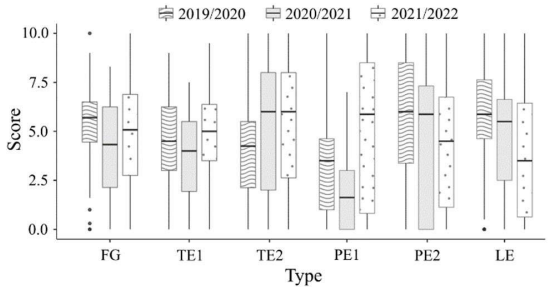

FIGURE 2. Boxplot for Final Grades (FG), Theory Exams (TE), Problems Exams (PE) and Laboratory Exam (LE) in all groups.

TABLE 3. Comparison among SEEQ survey factors.

Evaluation Activity	*p* value		
	Pre-ERL vs ERL	Pre-ERL vs Post-ERL	ERL vs Post-ERL
TE1 Theory Exam 1	0.060	0.487	**0.014**
TE2 Theory Exam 2	0.148	**0.023**	0.778
PE1 Problems Exam 1	**0.036**	**0.016**	**0.000**
PE2 Problems Exam 2	0.426	0.063	0.419
LE Laboratory Exam	0.179	**0.000**	0.087
FG Final Grades	0.064	0.400	0.254

*Mann-Whitney *U* test. Bold values: p<0.05.

Table 2 shows the grades distribution in all courses split by the different theory, problems and laboratory exams that were held. Additionally, Mann-Whitney *U* tests have been performed to establish comparisons among courses (see Table 3).

As presented in Table 2, during mid-semester, both Theory Exam 1 (TE1) and Problems Exam 1 (PE1) took place. It can be observed how grades distribution decreased during ERL, with a subsequent rise where post-ERL performance could even overcome pre-ERL levels. Though there is no significant difference between pre-ERL and ERL scenarios in the case of TE1, a significant recovery is registered during post-ERL, recovering the grades levels from pre-ERL course. Additionally, there is a significant reduction for PE1 in the ERL scenario, as well as significant improvement in post-ERL scenario when compared to both pre-ERL and ERL.

End-semester examinations consisted of Theory Exam 2, Problems Exam 2, and Laboratory Exam. TE2 shows a significant grade increase in the post-ERL scenario, while PE2 grades stay stable during both ERL and post-ERL. Finally, LE shows a similar grades profile to PE2, where there are no significant differences between the pre-ERL and the ERL scenarios, but a significant decrease is found when comparing pre-ERL and post-ERL scenarios.

C. PHASE 3: IMPLICATIONS OF THE USE OF DIDACTIC VIDEOS

Previous quantitative results show the impact of ERL in the perception of education quality and academic performance.

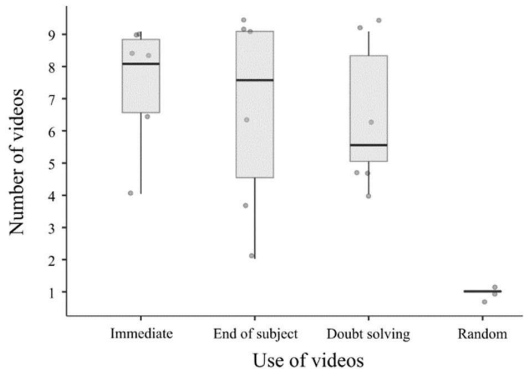

FIGURE 3. Number of videos watched related to their use.

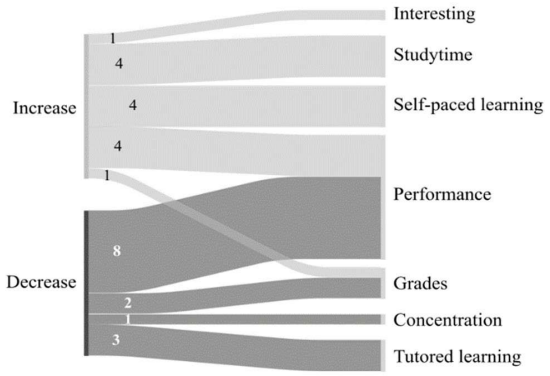

FIGURE 4. Sankey diagram for the subjective perception of ERL effects in performance and learning related parameters.

However, the implications of the integration of didactic videos during this experience could be better appreciated through a qualitative approach that allows to understand to which extent they were helpful in mitigating the negative effects of ERL, by helping conceptual learning and raising interest among students.

First, participants in the qualitative assessment were asked to declare whether they used videos as soon as they were available, at the end of the course, as conceptual aid for clearing doubts, or randomly. Table 3 shows the number of videos watched related to declared use. Out of the nine videos provided, a mean of 7.33 (SD 1.97) were watched immediately after release. Other students decided to use all videos together once the course finishes, in order to prepare their final examinations. In this case, a mean of 6.5 (SD 3.02) videos are watched. When referring to clarify doubts, a mean of 6.33 (SD 2.16) videos are watched at a variable pace depending on when the conceptual aid is needed. Finally, random use is declared by three students, and it refers to the reproduction of a randomly chosen video for curiosity, but without further use of these resources.

After collecting the 21 participations in the structured interview, the resulting text was coded following a deductive process as described in the Methodology section. In order to analyze the codependency of the main ideas transmitted by participants, a cooccurrence analysis has been developed, and its results are presented through Sankey diagrams to visually understand those connections. These kinds of representations allow us to visualize the relations between the concepts on the left and the concepts on the right, through the number of cooccurrences between them found during the interview. This number is indicated on the left side of the graphic and, additionally, the more cooccurrences are found in students' participations the thicker the flow lines will be.

ERL impact in academic performance and other learning descriptors is represented in Table 4, where 8 cooccurrences declare a decrease in performance. This is also related with a perceived decrease of tutored learning and concentration. However, up to 4 cooccurrences from other participants are found indicating an increase in this same descriptor, related to an increase of self-paced learning options, study time and interest in the subject.

As regards the videos' specific impact, Figure 5 shows the main learning-related parameters related to the specific benefit extracted from videos.

In terms of facilitating conceptual learning, videos are found to be useful to understand subject's concepts mainly because they can be viewed several times and allow to clarify doubts through self-paced learning. Additionally, the available videos are considered a positive complement to the professor's explanations due to their didactic value, as well as individual learning descriptors previously mentioned. Some participants also highlight their specific value to visualize abstract ideas present in STEM.

Regarding videos' impact on the enhancement of motivation and interest in the subject, the main highlighted metric refers to their didactic value. Other participants see a connection between this aspect and their added value for the visualization of abstract ideas, as well as their practical and direct explanation style. As for this practical focus of videos, some students consider it relevant that the contents are created by a professional in electrical engineering, as it helps them to discover professional applications and integrate the studied concepts into the big picture of the degree.

IV. DISCUSSION

The ERL unprecedented conditions imposed by the covid-19 lockdown had several implications, and our results show interesting insights in this regard. This section intends to answer the proposed research questions as per our findings.

A. RQ1: DID ERL PRODUCE DIFFERENCES IN EDUCATION QUALITY PERCEPTION AND ACADEMIC PERFORMANCE?

Through SEEQ survey (see Appendix II for detailed results), we were able to quantify a significant reduction in Learning and Enthusiasm factors, mainly because of a reduction in understanding of the subject's contents, and a decrease of interest in professor's presentations. The ERL improvised

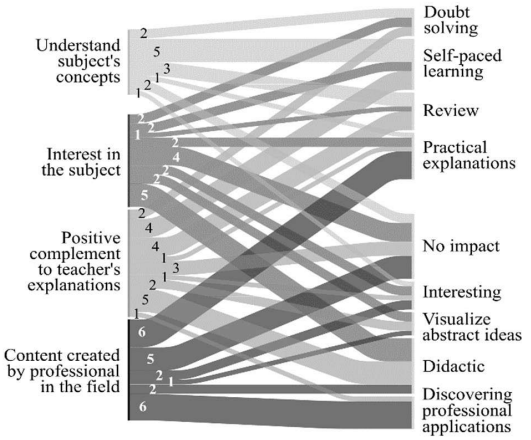

FIGURE 5. Sankey diagram for videos' implications in conceptual learning, interest, and value from the professional perspective.

environment might have affected the professor's comfort, conditioning his ability to deliver engaging presentations of the subject's contents and also incorporating the use of humor. This is particularly relevant, as it shows how ERL did not only affect students' perception of their learning outcomes, but also of their professors' ability to contribute to students' motivation and interest in the subject through engaging presentations. These findings are consistent with Tulaskar and Turunen's, after conducting their research based on surveys, semi-structured interviews and diary studies [1]. Through a survey with 138 participants, 61% reported a negative experience with ERL, mainly related to an uninteresting presentation and a non-interactive way of teaching. Additionally, they measured a moderate satisfaction perception of learning quality (3.42 score on a 5-point Likert scale).

Performance in evaluation activities differed slightly, but there are not significant differences between pre-ERL and ERL situations excepting PE1. This fact is consistent with the initial difficulties of ERL, which in this case study has had a higher impact in procedural learning. Tulaskar and Turunen's measures of students' adjustment, and acceptance of the situation during the progress of the course, are also consistent with the improvement in performance from mid-semester to end-semester examinations measured in our study for ERL [1].

Regarding active participation during synchronous classes, SEEQ survey unveiled an increase from pre-ERL to ERL, mainly associated to professors' increased proactivity towards students' expressing their ideas, asking questions, and participating in class discussions. This is common practice in Electrical Machines I subject at this university, which is consistently taught with high students' participation component, but isolation and the new learning environment imposed by ERL conditioned the professor to further insist on the importance of group interaction.

However, despite this is true for synchronous classes, it might not be representative of the whole learning experience. Other negative effects of ERL quantified by the qualitative assessment are related with a perceived decrease in tutored learning and concentration, also reported by Tulaskar and Turunen [1]. A reduction in professor's accessibility was also significant as per SEEQ's results, in keeping with qualitative findings of a perceived decrease in tutored learning. This is also related to the grades and performance decrease reported by some students, as shown in Table 4. Feedback on graded assignments, as well as instructor's emphasis on key concepts for evaluation also decreased during ERL. However, overall assessment of the degree's professors performed by the Electrical Engineering Department confirms that "Electrical Machines I" professor is among the most valued professors of the degree during the pre-ERL, the ERL and the post-ERL scenario, specifically due to the pedagogical tools used for online teaching. A similar case study performed in other subjects might unveil higher impact among scenarios. Concerning these aspects, Gopal et al. [4] measured that instructor's quality is the main factor affecting student's satisfaction during online classes, followed by students' expectations and feedback. They concluded that instructors need to be more creative in designing and delivering course contents to improve overall satisfaction.

This appreciation might be related to results in the perception of the course's assignments. Measured impact through the SEEQ mainly refers to proposed reading and homework, whose value for students was significantly reduced. However, the didactic videos made available during the course did have a remarkable impact on students, as reported through qualitative assessment.

B. RQ2: DID DIDACTIC VIDEOS CONTRIBUTE TO MITIGATE THE IMPACT OF ERL FROM THE STUDENTS' PERSPECTIVE?

Quantitative approach in this article has intended to evaluate ERL impact on students' perception on education quality and performance, but with only that information it is not possible to isolate the effect of videos in such scenario. However, despite previously mentioned negative impacts of ERL, nuances extracted from qualitative assessment indicates that there are also positive impacts for students that participated in this study, mainly related to an increase in autonomous study fostered by video-aided active learning. Table 4 shows that some participants declared an increase in performance and interest during ERL thanks to the new possibilities for self-paced learning, as well as study time increase promoted by provided video resources. Self-paced learning is also highlighted by Shoufan, as a consequence of his experience with fully active learning [10]. Additionally, in Kim and Ahn experience with video-aided flipped classroom learning, an increase of 25% in class time was quantified, as well as an engagement increase from students in the learning process by the possibility to self-regulate their study pace, and the option of repeatedly watching proposed video clips [17].

This repeatability factor is also highlighted by Tiernan and O'Kelly [15].

Participants stated that videos contributed to understand the subject's concepts, and they were a positive complement to professor's explanations, mainly because they allowed to repeatedly watch conceptual explanations and solving doubts at a self-paced rhythm with didactic explanations. As unveiled during the initial stage of qualitative assessment, a mean of 6.33 (SD 2.16) videos were watched for doubt-solving purposes, at a variable pace depending on needs for conceptual aid. In the framework of CLT, Tani et al. concluded that multimedia presentations such as video might increase academic performance, specifically in procedural and evaluative knowledge [14]. There is wide evidence that video integration in education with procedural learning fosters problem-solving activities [21], [34], [45]. However, related to conceptual learning, Song and Kapur have also highlighted positive results of video integration with prior concept discussion and problem resolution in tutored activities during class, which is consistent with our findings [46]. This backs up the differences on Theory Exams and Problems Exams, where conceptual learning promoted by video integration is found to be useful to mitigate ERL impact for both TE1 and TE2. The main detected impact of ERL in academic performance relates to problems and laboratory tests, where in theory examinations videos might have acted as a mitigating tool by supporting conceptual learning. It is worth mentioning that end-semester theory examinations normally show better results than mid-semester ones, because students incorporate and assimilate concepts during the whole course, hinting at an intrinsic enhancement in performance.

Students highlighted the fact that proposed didactic videos allowed them to visualize more clearly abstract concepts, which enhanced the didactic experience. This is supported by CTML, as the dual channel (visual and auditory) reduces the cognitive load the student is exposed, and visual animations help understanding abstract ideas [5], [6], [7]. Additionally, this is consistent with findings from Asef and Kalyvas [47], quantifying the central role of animations in promoting conceptual learning through videos, with rates of 68% of positive responses from undergraduate students (including very significant and significant), and 86% from postgraduate students. Moreover, the same study highlights that respectively 75% and 82% of undergraduate and post-graduate students indicate that they prefer animated videos instead of traditional video recordings to understand real-world technology. Tiernan and O'Kelly [15] also highlight students' feedback of videos' specific value to visualize information, as well as to provide practical explanations, concluding to a generalized agreement from students that the learning value of video is higher than compared to books alone.

Our findings from qualitative assessment, and their match with observations from quantitative assessment and literature, suggest that didactic videos could present a mitigating effect for some of the negative effects of ERL, mainly due to their support to conceptual learning, and their contribution to increasing study time and self-paced learning. However, they were not enough to fully compensate such an unprecedented change of paradigm, but instead act as a cushioning measure.

C. RQ3: DID DIDACTIC VIDEOS CONTRIBUTE TO BOOST MOTIVATION AND INTEREST IN THE SUBJECT?

As previously discussed, though ERL had a substantial impact in students' perception of education quality, didactic videos played a mitigating role, especially regarding conceptual support during the course. This had a specific effect in academic performance of theory exams. But, when focusing on motivation and the interest on the subject, didactic videos' implications are even more noticeable.

Though finding suitable videos online for education is usually challenging from teachers' perspective, Pattier highlights that the most frequent selection criterion is a video's potential to generate motivation in students, followed by its relevance for the objectives of the subject and its expositive clarity [18]. The aspect of the motivational value of videos as a main driver is also highlighted by Tiernan and O'Kelly [15], after quantifying in their qualitative study how a wide majority of their students and teachers reported that videos helped to increase attention during classes, as well as to raise of the interest in the subject. They also highlight that it is essential to ensure that videos are relevant for students, and their contents are not only interesting, but also show an adequate difficulty level. This aspect is confirmed for videos created by the *Sígueme la Corriente* channel, including those considered in this study, where positive perception has been quantified for both content and format adequacy, as well as the engaging style of the presenter and the usefulness of the contents to understand topics of interest [11]. Global positive evaluation of *Sígueme la Corriente* educational value is also consistent with Shoufan's findings [36], that highlight a set of 6 reasoning clusters determinant for students to like or dislike educational videos: explanation quality, audiovisual quality, content, efficient length, voice and language, and interestingness.

Didactic video integration was also able to raise the interest in the subject, as highlighted by participants in qualitative assessment. This is mainly related to video support to visualize abstract concepts, widely present in STEM disciplines and, particularly, in electrical engineering. Previous studies by Horta-Bernus and Casals-Rosas explain how phasor diagrams are helpful for students to understand abstract concepts in electrical engineering, due to the complex mathematics involved in this field [48]. Additionally, Wu et al. concluded that drawing prompts are useful tools for problem-solving strategies in engineering. [49]. These aspects are consistent with our study's premise, where developed videos included an enhanced version of phasor diagrams due to the possibility of including animated drawings.

Additionally, the fact that videos were created by an active professional was also valued from students, as they included interesting practical explanations that allowed them to discover the professional applications of electrical engineering. This contributes to create a global perception of the degree's contents, as well as connecting key concepts among subjects that would otherwise be presented separately and unlinked. Conclusions from Cabrera-Peña et al. are aligned in this regard, highlighting the need to connect concepts belonging to different engineering courses [9]. Moreover, Maciejewsky et al. also support this perspective, with a specific focus in those disciplines more abstract such as electrical engineering [8]. This practical use of videos to enhance a complete understanding of the degree's implications and applications also contributes to influence some of the main reasons for dropout rates in engineering studies, which are additionally increased by online learning modality [50], [51].

Overall, qualitative participations show that didactic videos had a positive impact in both motivation and a raise of interest in the subject's contents. According to Soufan's experience with fully active learning [10], successful integration of multimedia resources promotes a high level of perceived interest in students, as well as a reduction in boredom levels. Additionally, Gordillo et al. experience with video-based learning measured a positive perception from students on video integration for online software engineering education [52], where most students stated that video-based methodology helped them learn (with a mean of 4 in a 5-point Likert scale).

V. CONCLUSION

Didactic video integration has proven to provide an overall positive impact in this study, with beneficial implications in conceptual learning and performance, as well as interest and motivation. They have also shown a positive mitigating effect on some of the most impacting challenges of ERL during covid-19 lockdown, as well as a positive contribution during post-ERL scenario. Additionally, this study shows how an adequate selection of topics through conceptual mapping of subjects is able to promote video-aided reinforcement for the global perspective of the degree through conceptual connections. The practical perspective of provided videos has also been beneficial to provide first-hand prospects of the professional applications of the degree. The challenge remains in professor's acceptance and integration of these resources and active methodologies, which could be fostered by an enhancement on their pedagogical knowledge as complementary to the normal specialization in their respective STEM discipline, based on TPACK model and its particularized ICT-TPACK.

VI. LIMITATIONS AND FUTURE WORKS

The main limitation of this study is related to the irruption of ERL and the required change in learning methodologies, which implies difficulties for the proper isolation of either

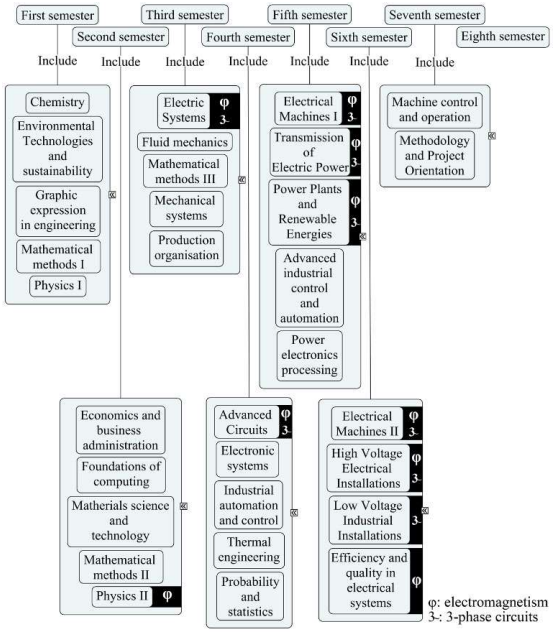

FIGURE 6. Concept map of compulsory subjects in BSc in Electrical Engineering, marking those related to electromagnetism (ϕ symbol) and 3-phase circuits (3L4 symbol).

videos or ERL effects on education quality perception and performance parameters through a quantitative approach. It is not possible to isolate one effect from the other, as both coexisted in time and had mixed implications. Therefore, qualitative assessment has allowed to collect specific information on video impact, which has been beneficial for the interpretation of perceived videos' benefits for above mentioned parameters, as well as their additional benefits for students' motivation and interest. Additionally, this study has been conducted during three academic years, and has focused on a specific course of the electrical engineering degree in only one university. Its results are representative of the specific case of electrical engineering studies in a public university. More case studies in similar environments might provide additional evidence of videos implications in electrical engineering education during ERL, as well as to further extend the findings of this article and extrapolate them to other learning situations.

With a view to overcoming the main limitation of this study, proposed future works include the extent of a similar case study in future academic years, once presential learning is fully reinstated. This will allow to evaluate the specific impact of didactic videos by means of a direct comparison with the pre-ERL scenario, as well as contrasting obtained results for the main factors where videos acted as mitigating resource for ERL negative impacts during ERL scenario. Additionally, other sources of didactic videos will be evaluated to further explore the educational use of scientific dissemination in a wider variety of STEM disciplines.

TABLE 4. Students' Evaluation of Educational Quality survey results, distinguishing between factors: F1 Learning, F2 Enthusiasm, F3 Organization, F4 Group Interaction, F5 Individual rapport, F6 Breadth, F7 Exams, F8 Assignments, and F9 Overall.

Factors		Questions	Control		Experimental				*p* value*		
			2019/2020		2020/2021		2021/2022		'19/'20 vs '20/'21	'19/'20 vs '21/'22	'20/'21 vs '21/'22
			Mean	SD	Mean	SD	Mean	SD			
F1	1	I have found the subject intellectually challenging and stimulating	4.44	0.847	4.22	0.671	4.43	0.698	0.111	0.723	0.179
	2	I have learned something which I consider valuable	4.56	0.892	4.39	0.583	4.49	0.742	0.098	0.439	0.337
	3	My interest in the theme has increased because of this subject	4.26	0.944	3.74	1.210	4.23	0.877	0.112	0.811	0.132
	4	I have learned and understood the contents of this course	4.11	0.847	3.30	1.260	4.03	0.857	**0.009**	0.646	**0.026**
F2	5	The professor was enthusiastic about teaching the subject	4.89	0.320	4.87	0.344	4.71	0.789	0.836	0.465	0.622
	6	The professor was dynamic and energetic in conducting the subject	4.78	0.641	4.57	0.662	4.66	0.684	0.111	0.312	0.467
	7	The professor enhanced presentations with the use of humor	4.70	0.609	4.17	0.984	4.57	0.739	**0.016**	0.440	0.061
	8	Professor's style of presentation held my interest during class	4.48	0.753	3.52	1.160	4.31	0.832	**0.001**	0.418	**0.006**
F3	9	Professor's explanations were clear	4.67	0.480	4.35	0.647	4.37	0.843	0.071	0.162	0.614
	10	Subject materials were well prepared and carefully explained	4.30	0.869	4.30	0.822	4.40	0.812	0.983	0.534	0.584
	11	Proposed objectives agreed with those actually taught so I knew where the subject was going	4.44	0.801	4.09	0.848	4.46	0.780	0.090	0.961	0.065
	12	The professor gave lectures that facilitated taking notes	4.26	0.903	4.26	0.864	4.34	0.802	0.992	0.726	0.741
F4	13	Students were encouraged to participate in class discussions	4.48	0.753	4.65	0.647	4.37	0.731	0.333	0.474	0.106
	14	Students were invited to share their ideas and knowledge	4.33	1.040	4.61	0.722	4.40	0.695	0.307	0.739	0.160
	15	Students were encouraged to ask questions and were given meaningful answers	4.67	0.480	4.70	0.470	4.54	0.611	0.828	0.496	0.389
	16	Students were encouraged to express their own ideas	4.44	0.698	4.48	0.790	4.23	0.942	0.689	0.439	0.281
F5	17	The professor was friendly towards individual students	4.74	0.813	4.35	0.832	4.57	0.558	**0.014**	**0.042**	0.389
	18	The professor made students feel welcome in seeking help/advice in or outside of class	4.93	0.267	4.52	0.947	4.57	0.778	**0.032**	**0.012**	0.885
	19	The professor had a genuine interest in individual students	4.74	0.813	4.70	0.470	4.69	0.583	0.223	0.317	0.806
	20	The professor was adequately accessible to students during office hours of after class	4.70	0.823	4.50	0.512	4.63	0.547	**0.030**	0.198	0.291
F6	21	The professor contrasted the implications of various theories	4.08	0.935	3.87	0.920	4.00	0.874	0.368	0.634	0.665
	22	The professor presented the background or origin of ideas/concepts in or outside of class	4.44	0.577	4.00	0.853	4.31	0.796	0.053	0.700	0.133
	23	The professor presented points of view other than his/her own when appropriate	4.11	0.934	3.83	0.834	3.94	0.851	0.140	0.334	0.490
	24	The professor adequately discussed current developments in the field	4.33	0.920	4.13	0.757	4.46	0.741	0.188	0.649	0.063
F7	25	Feedback on examinations/graded materials was valuable	4.37	0.884	3.70	1.220	4.06	1.030	**0.034**	0.227	0.267
	26	Methods of evaluating student work were fair and appropriate	4.48	0.849	3.57	0.992	4.00	1.080	**0.000**	0.061	0.071
	27	Examinations/graded materials tested course content as emphasized by the instructor	4.70	0.823	4.22	1.130	4.37	0.910	**0.045**	**0.046**	0.748
F8	28	Required readings/texts were valuable	4.07	0.958	3.67	0.557	3.82	0.999	**0.032**	0.267	0.395
	29	Reading, homework, laboratories contributed to appreciation and understanding of subject	4.44	0.847	3.70	0.876	4.14	0.974	**0.001**	0.165	**0.038**
F9	30	Compared with other subjects I have had at the university, I would say this one is:	4.52	0.849	4.26	0.689	4.49	0.702	0.079	0.633	0.159
	31	Compared with other professors I have had at the university, I would say this one is:	4.70	0.542	4.74	0.449	4.71	0.572	0.949	0.827	0.881
	32	As an overall rating, I would say the professor is:	4.67	0.555	4.65	0.487	4.63	0.690	0.774	0.979	0.738

*Mann-Whitney *U* test. Bold values: p<0.05.

From professors' perspective, future works will include specific evaluations of their ICT acceptance, including specific training programs on digital competencies intended to improve professors' predisposition to foster ICT-aided active methodologies.

APPENDIX I. CONCEPT MAPS

Concept maps have been used as a helping tool to confirm our hypothesis that Electromagnetism and 3-phase circuits are key concepts to implement video-aided reinforcement. As a first step, we have analyzed the itinerary that all students will follow in the degree for our experimental case [30]. To provide a broad picture of the context, Figure 6 shows each compulsory subject within the different semesters of the degree, highlighting those that are related to electromagnetism (φ symbol) and 3-phase circuits ($3\sim$symbol) as our target concepts. It can be appreciated how these concepts are of relevance for the electrical engineering curriculum,

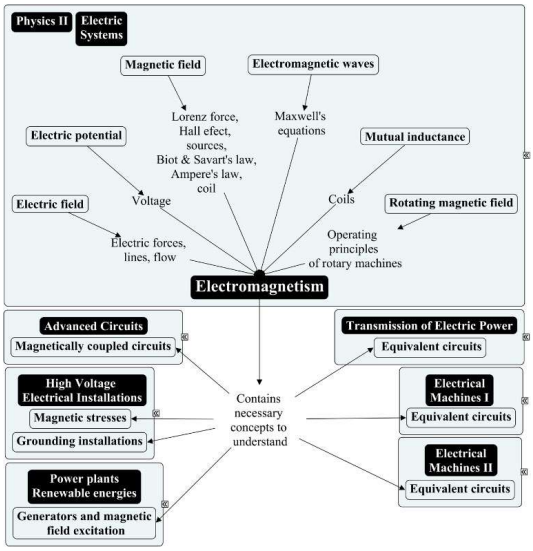

FIGURE 7. Concept map detailing both the concepts preceding electromagnetism and the concepts to which electromagnetism understanding is needed.

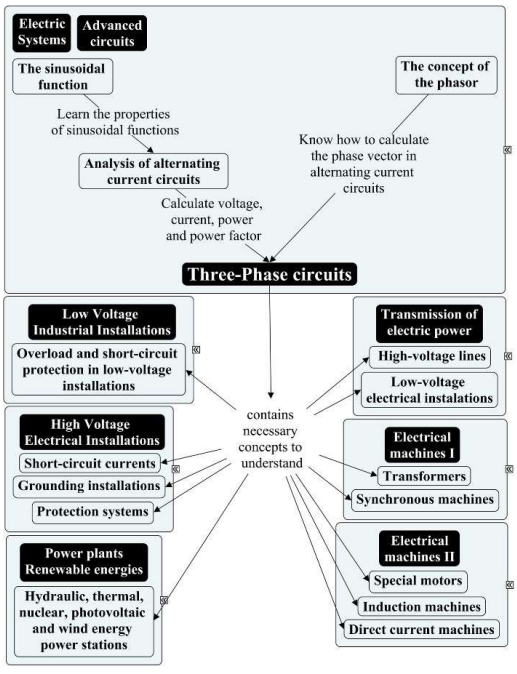

FIGURE 8. Concept map detailing both the concepts preceding 3-phase circuits and the concepts to which 3-phase circuits understanding is needed.

since they are directly related to 10 subjects (32.2% of all compulsory subjects).

However, what is the nature of the relation among those subjects from the perspective of both concepts? Figure 7 and Figure 8 present a detailed view showing the selected concepts. Above them, previous base concepts needed for their understanding are detailed. Below, additional concepts that need to be mastered are developed, in order to properly understand each subject.

After an analysis of the contents included in these 10 highlighted subjects and the time dedication foreseen in their study [30], it is observed that electromagnetism and 3-phase circuits are necessary concepts to understand from 20% to 80% of each one of these subjects. Therefore, this concept can be considered as a bottleneck for 32.2% of the courses that make up the electrical engineering degree, starting with "Electrical Machines I" as one of the first specialization subjects that students will face (taught in parallel to Transmission of Electric Power, and Power Plants and Renewable Energies).

APPENDIX II. SEEQ SURVEY

This appendix shows the results for each question in the SEEQ survey, detailing in Table 4 which are the specific questions grouped in each factor, as well as mean scores and standard deviation for each year comprising the study. The 9 factors considered in this questionnaire are: F1 Learning, F2 Enthusiasm, F3 Organization, F4 Group Interaction, F5 Individual rapport, F6 Breadth, F7 Exams, F8 Assignments, and F9 Overall. Additionally, the courses included are 2019/2020 (pre-ERL), 2020/2021 (ERL) and 2021/2022 (post-ERL). Additionally, p values are shown for statistical significance of the comparison among academic years.

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7

THIRD JOURNAL ARTICLE

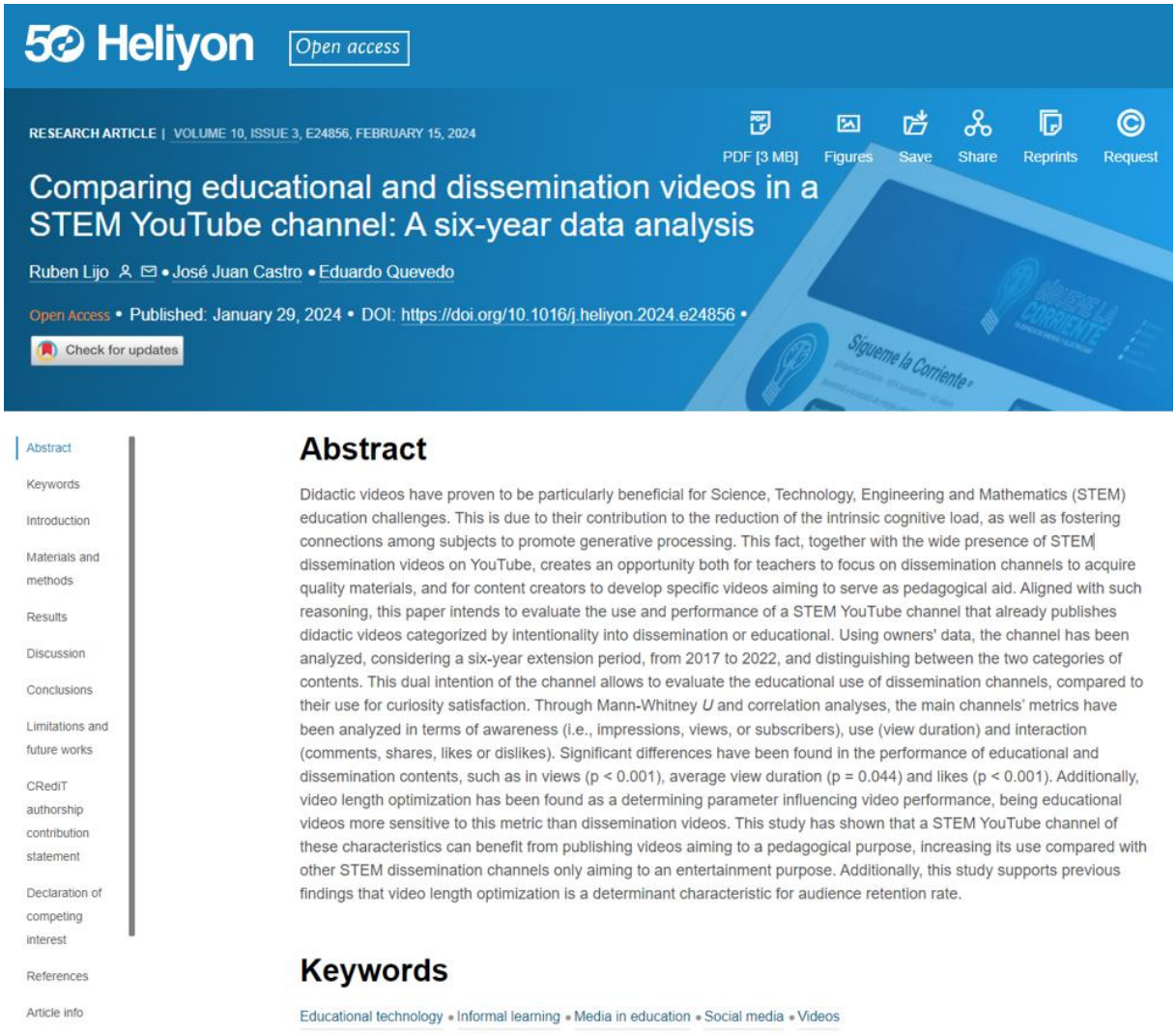
COMPARING EDUCATIONAL AND DISSEMINATION VIDEOS IN A STEM YOUTUBE CHANNEL: A SIX-YEAR DATA ANALYSIS

7. Third journal article: Comparing Educational and Dissemination Videos in a STEM YouTube Channel: A Six-Year Data Analysis

7.1 Article's Main Information

- **Journal:** Heliyon (Volume: 10, Issue 3).
- **Section:** Education.
- **Indexed in:** Heliyon is included in the Clarivate Analytics Web of Science, which includes Science Citations Index Expanded. Heliyon has an impact factor of 4, an Eigenfactor of 0.04338, a five-year impact factor of 4.1 (Q2), and an immediacy index of 0.6 (per 2022 JCR). This journal is also included in Scopus, with a CiteScore of 5.6 (per 2022 JCR) and a Scimago Journal Rank of 0.617 (Q1) (per 2023 SJR). Moreover, Heliyon is also indexed by PubMed Central, and listed in the Directory of Open Access Journals (DOAJ).
- **Publisher:** Elsevier (Cell Press).
- **Pages:** 1 – 17.
- **Date of publication:** 29 January 2024.
- **ISSN:** 2405-8440.
- **DOI:** 10.1016/J.HELIYON.2024.E24856.

Cite this article as: R. Lijo, J. J. Castro and E. Quevedo, "Comparing Educational and Dissemination Videos in a STEM YouTube Channel: A Six-Year Data Analysis," in Heliyon, vol. 10(3), pp. 11-17, 2024, doi: 10.1016/J.HELIYON.2024.E24856.



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Comparing educational and dissemination videos in a STEM YouTube channel: A six-year data analysis

Ruben Lijo • José Juan Castro • Eduardo Quevedo

Open Access • Published: January 29, 2024 • DOI: https://doi.org/10.1016/j.heliyon.2024.e24856 •

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Abstract

Didactic videos have proven to be particularly beneficial for Science, Technology, Engineering and Mathematics (STEM) education challenges. This is due to their contribution to the reduction of the intrinsic cognitive load, as well as fostering connections among subjects to promote generative processing. This fact, together with the wide presence of STEM dissemination videos on YouTube, creates an opportunity both for teachers to focus on dissemination channels to acquire quality materials, and for content creators to develop specific videos aiming to serve as pedagogical aid. Aligned with such reasoning, this paper intends to evaluate the use and performance of a STEM YouTube channel that already publishes didactic videos categorized by intentionality into dissemination or educational. Using owners' data, the channel has been analyzed, considering a six-year extension period, from 2017 to 2022, and distinguishing between the two categories of contents. This dual intention of the channel allows to evaluate the educational use of dissemination channels, compared to their use for curiosity satisfaction. Through Mann-Whitney *U* and correlation analyses, the main channels' metrics have been analyzed in terms of awareness (i.e., impressions, views, or subscribers), use (view duration) and interaction (comments, shares, likes or dislikes). Significant differences have been found in the performance of educational and dissemination contents, such as in views ($p < 0.001$), average view duration ($p = 0.044$) and likes ($p < 0.001$). Additionally, video length optimization has been found as a determining parameter influencing video performance, being educational videos more sensitive to this metric than dissemination videos. This study has shown that a STEM YouTube channel of these characteristics can benefit from publishing videos aiming to a pedagogical purpose, increasing its use compared with other STEM dissemination channels only aiming to an entertainment purpose. Additionally, this study supports previous findings that video length optimization is a determinant characteristic for audience retention rate.

Keywords

Educational technology • Informal learning • Media in education • Social media • Videos

Figure 27. Online publication of the article 3 at Cell Press.

7.2 Embedded Article

Heliyon 10 (2024) e24856

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Comparing educational and dissemination videos in a STEM YouTube channel: A six-year data analysis

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ARTICLE INFO

Keywords:
Educational technology
Informal learning
Media in education
Social media
Videos

ABSTRACT

Didactic videos have proven to be particularly beneficial for Science, Technology, Engineering and Mathematics (STEM) education challenges. This is due to their contribution to the reduction of the intrinsic cognitive load, as well as fostering connections among subjects to promote generative processing. This fact, together with the wide presence of STEM dissemination videos on YouTube, creates an opportunity both for teachers to focus on dissemination channels to acquire quality materials, and for content creators to develop specific videos aiming to serve as pedagogical aid. Aligned with such reasoning, this paper intends to evaluate the use and performance of a STEM YouTube channel that already publishes didactic videos categorized by intentionality into dissemination or educational. Using owners' data, the channel has been analyzed, considering a six-year extension period, from 2017 to 2022, and distinguishing between the two categories of contents. This dual intention of the channel allows to evaluate the educational use of dissemination channels, compared to their use for curiosity satisfaction. Through Mann-Whitney *U* and correlation analyses, the main channels' metrics have been analyzed in terms of awareness (i.e., impressions, views, or subscribers), use (view duration) and interaction (comments, shares, likes or dislikes). Significant differences have been found in the performance of educational and dissemination contents, such as in views ($p < 0.001$), average view duration ($p = 0.044$) and likes ($p < 0.001$). Additionally, video length optimization has been found as a determining parameter influencing video performance, being educational videos more sensitive to this metric than dissemination videos. This study has shown that a STEM YouTube channel of these characteristics can benefit from publishing videos aiming to a pedagogical purpose, increasing its use compared with other STEM dissemination channels only aiming to an entertainment purpose. Additionally, this study supports previous findings that video length optimization is a determinant characteristic for audience retention rate.

1. Introduction

Informal educational videos in social media provides an alternative world-reaching method to disseminate information, delivering

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https://doi.org/10.1016/j.heliyon.2024.e24856
Received 19 December 2023; Received in revised form 12 January 2024; Accepted 16 January 2024
Available online 30 January 2024

additional resources that might enrich formal and informal education. YouTube is currently the main platform for such use [1–3], and particularly the role of edutubers (educational content creators in YouTube) is impacting education in a context where audiovisual content is highly demanded by the new generations of students [4].

The Cognitive Theory of Multimedia Learning (CTML), based on the Cognitive Load Theory (CTL), explains how multimedia material can positively impact processing capacity based on two main aspects: the reduction of extraneous cognitive load and the fostering of generative processing [5,6]. However, as highlighted by Shoufan and Mohamed [7], we still don't know how these principles could be applied to the selection of YouTube videos for students nor the optimal integration strategy into the teaching and learning process. Several authors highlight the need of new replication and comparative studies to understand the impact of YouTube in learning [7–9].

1.1. What aspects define adequate didactic videos? Format, user preferences and integration challenges

There is consensus among the main parameters that make didactic videos be perceived of good quality for pedagogical aid in STEM disciplines. Such parameters highlight audiovisual format aspects such as production quality and visualization of contents, video length optimization, explanation rhythm, technical accuracy and completeness, the use of examples and linking contents to prior knowledge, and an engaging communication style [10–13].

Particularly for the case of video length, several authors highlight its importance for videos to be considered engaging. This is directly related to the retention rate, which measures the average percentage of the video that has been effectively watched by the audience. Doolittle et al. [14] found, as part of their study on 212 undergraduate students, that shorter instructional tutorials promote engagement and, therefore, videos use for learning. This is also aligned with findings by Guo et al. [15] for Massive Online Open Courses (MOOC) environments. Furthermore, Pi and Hong [16] performed an eye-tracking analysis to reveal when mental fatigue appears while watching educational video podcasts. They concluded that mental fatigue started at 10 min and reached a peak at 22 min, recommending keeping videos shorter than 10 min whenever possible. Altman and Jiménez [17] also relate video length with retention rate, concluding that videos with low retention rate could potentially increase their audience engagement by shortening their length. However, it is important to consider that the possibility to shorten an educational video should be strictly conditioned by such video's contents. In this regard, Shoufan [18] appeals to the concept of efficiency in explanations, by addressing the videos' topics in a direct and concise way, rather than just shortening videos to meet a numerical video length target. Additionally, regarding other YouTube video metrics such as likes or dislikes, Shoufan & Mohamed [19] concluded that video length does not present a significant correlation.

Previous works have researched which parameters do motivate students to like or dislike educational videos, which are mainly related to the explanation quality, audiovisual presentation and interest generated [4,18]. Additionally, other authors have detailed a series of pedagogical benefits of YouTube videos, such as the enhancement of academic performance [20–23], the acquisition of new transversal and specific competencies [24], and the increasement of student motivation and satisfaction [25–27]. The following characteristics of YouTube videos are highlighted in such literature as useful for educational environments: providing a summary of the subject's contents, being able to clarify complex phenomena and abstract ideas through visual support, and providing models of professional skills and behaviors. In this context, the fact that other students or professionals create videos also reinforces specialized jargon learning and helps fostering virtual and collaborative learning [28].

The challenge relies on the creation of videos that are more adapted to pedagogical needs, as well as in providing adequate tools and competencies to the teaching community for the appropriate selection of educational videos [29–31]. This would avoid the potential negative effects of resorting to YouTube videos for educational purposes, such as the attention reduction or the lack of scientific rigor [32,33].

The suitable search of YouTube videos for education is complex, not only because of the huge number of videos published in the platform [34], but also due to the popularity-driven search and recommendation algorithm of YouTube [35,36]. According to a recent review on the educational use of YouTube, almost 81 % of analyzed videos for potential educational use fall into "poor quality' category [7]. Furthermore, learners tend to select their reference videos from the top of the searching list [37], which increases the challenge of appropriately delivering adequate videos to students as pedagogical aid.

However, the platform also hosts a large quantity of high-quality videos in a wide variety of knowledge domains [1]. Current evidence points out that the optimal strategy would be using YouTube for guided learning, where teachers assume the role of creating or selecting the most suitable videos within a defined pedagogical context. Evidence from previous research shows that teachers did not present resistance to incorporate Information and Communication Technologies (ICT) into their lectures, though their satisfaction in the use of ICT such as videos is associated with their level of digital competence [38,39]. Therefore, it is fundamental that they adequately develop their digital and pedagogical knowledge, according to the Digital Competence Framework for Educators (DigCompEdu) or Technological Pedagogical Content Knowledge (TPACK) [40,41].

In this context, both teachers and content creators could benefit each other from the specific consideration of the pedagogical use from the very beginning of the content creation phase in STEM YouTube channels. Teachers, on the one hand, would benefit from content creators contemplating the creation of educational videos because of the increase of available good quality and suitable didactic videos to be integrated in their teaching dynamics. Content creators, on the other hand, would benefit from targeting these needs by accessing to a new population segment and use purpose that, while maintaining the social dissemination purpose of the channel, adds another dimension to the channel and contributes boosting its use and popularity.

Such consideration towards pedagogical purposes should include the curricular alignment of created contents so that their introduction as pedagogical aid is facilitated. Additionally, previously mentioned aspects related to video content and format adequacy

should be specifically considered and maximized to ensure the perception of such videos as of good quality for educational purposes. Such aspects include an adequate production quality and visualization of contents, video length optimization, adequate explanation rhythm, technical accuracy and completeness, using examples and linking contents to prior knowledge and ensuring an engaging communication style. Didactic videos created with a pedagogical intention, and considering these characteristics, will be referenced in this article as educational videos. Whereas other videos that are created with the solely purpose of satisfying curiosity and entertaining, not necessarily considering abovementioned characteristics, will be referenced as dissemination videos.

This rationale motivates the present study, where the dual use of YouTube channels for social dissemination and education purposes is comparatively analyzed. Among the investigations that use public data to evaluate educational YouTube channels, validated instruments have been developed such as the one proposed by Pattier [42] for this matter. It is based on a 41-item evaluation that relies on the foundations of current literature for the evaluation of parameters such as dependent variables (gender, educational stage and topic), statistics applied to YouTube channels, video structure, video recording and editing, personality of the content creator, use of the YouTube platform and use of other social media. However, according to Bärtl [36], not using owner's data might present some limitations, as social media data (and, particularly, YouTube data) can differ depending on the data collection method that is used. This also highlights the importance of using owner data whenever possible, so that the information collected is precise.

Few articles have been developed with information from the perspective of channel's owners, which could provide useful insights on how to produce better educational videos and how to enhance their integration in the classroom. The cases described by Saurabh and Gautam [9], Bello-Bravo et al. [43] and Yang et al. [3] are some of the very few available. Moreover, as far as authors are concerned, there are no previous analyses in literature comparing the performance of educational and dissemination contents in a STEM YouTube channel. This motivates the reasoning behind understanding how are both types of videos performing in the context of a STEM channel, and which kind of video is more demanded (depending on whether there is a more curiosity-driven or educational-driven interest).

1.2. *Sígueme la Corriente: combining educational and dissemination purposes*

Sígueme la Corriente[1] is a popular Spanish-speaking STEM YouTube channel, focused mainly on energy, electricity and sustainability (see Fig. 1). It was created in January 2017, and, since then, three main stages have taken place in its evolution: presentation, consolidation and reconceptualization.

Initially, the presentation stage took place during approximately the first two years of the channel, until April 2019. During this time, *Sígueme la Corriente* was devoted to creating interest and awareness about energy, electricity and sustainability topics and, therefore, specialized contents were interleaved between other general STEM topics to catch the public's attention. Additionally, during this period the channel's author also visited some TV and radio programs and participated in different national and regional events aiming to present the channel's activity to a wider audience.

The consolidation stage covered from April 2019 to August 2020. During this time, with a regular audience in the channel, *Sígueme la Corriente* focused all its new contents in energy, electricity and sustainability topics but always maintaining a dissemination purpose and voice. The main purpose was still to contribute to curiosity-satisfaction, public awareness, and the entertainment aim usually associated to YouTube. The channel's subscribers and views grew considerably, proving that the interest in such topics became increasingly more evident. Additionally, both teachers and students started asking for complementary contents that could be used in class or as a study material, also coinciding temporarily with the irruption of the Emergency Remote Learning (ERL) due to covid-19 pandemic. This is coherent with Elareshi et al. [44] analysis about YouTube's implications as an educational platform for higher education institutions during ERL, who emphasized that the adoption of this platform is highly recommended.

Pre-experimental academic assessments were set in place to help adequately answering those requests, aiming to verify the involuntary pedagogical use and potential value of the channel as per its audience perception [45,46]. As a conclusion, the reconceptualization stage began in August 2020 with the creation of a specific series of videos dedicated to serve as pedagogical aid, aiming to be integrated both in technological branches of secondary education and in energy, electricity or sustainability related university degrees. The remarkable growth in views, subscribers and use of the channel has been noticeable since then, though still a comprehensive analysis of these trends was missing.

Since *Sígueme la Corriente*'s inauguration on January 1st, 2017, up to December 31st, 2022, the channel has published a total of 147 videos, reaching 146,772 subscribers and 4,268,071 views. All videos have been categorized by a functional criterion, discretizing between "dissemination videos", "educational videos", and "others" for announcements, shorts or non-energy-related videos. The total number of videos published during this six-year time frame in each category is: 29 in education, 62 in dissemination and 56 in others.

These categories were set by intentionality. On the one hand, "dissemination videos" are those that aim to satisfy an entertainment use and curiosity, as well as contributing to the public's awareness on energy, electricity and sustainability. This type of videos has been created since the channel started operating and have continued being published during its six years of operation within the various thematic sections of the channel. In its creation, no specific constraints are considered in terms of topic selection nor format definition, other than presenting interesting and engaging topics to a broad audience. Some examples of videos' titles within this category would be: "How can you understand your electricity bill?", "How is Energy produced in the Matrix movies?", or "Could you be saved if a lightning strikes you?".

[1] https://youtube.com/SiguemeLaCorriente (Accessed 15/10/2023).

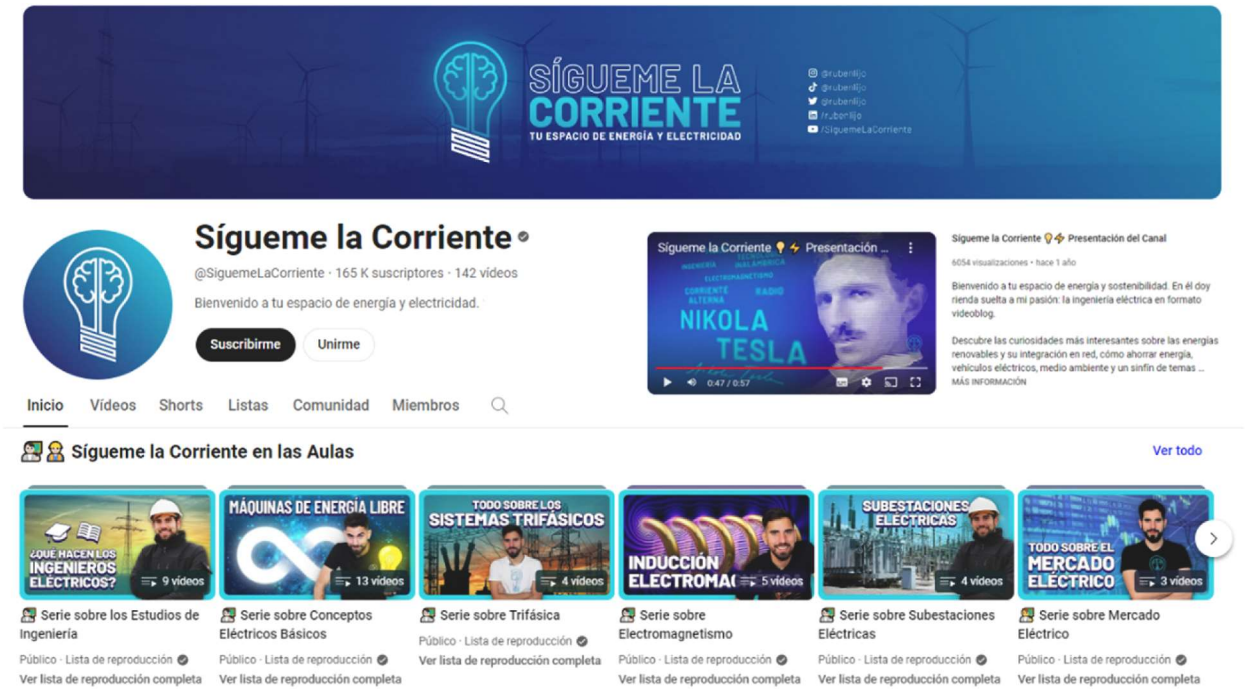

Fig. 1. Illustrative image of *Sígueme la Corriente* YouTube channel.

On the other hand, "educational videos" started to be created as such during the reconceptualization phase in August 2020. However, it is worth noticing that some previous contents were detected to also be compliant with the established criteria to fall under this category. From the presentation and consolidation stages, only a share of 24 % could be considered as educational, whereas during reconceptualization stage such share was set at 50 % (excluding "others" category from consideration in both cases). Educational contents in the channel respond to specific pedagogical requests from the audience (both students and teachers) and have been integrated in educational environments (either in secondary or university education). As opposed to dissemination contents, education contents in the channel are differentiated by the following specific features:

- They are specifically created to respond to a pedagogical demand from either teachers or students. Therefore, are aligned to specific subjects' contents of degrees in STEM formal education.
- They count on a deeper focus and more efficient explanations when compared to dissemination videos, and the communicative voice avoids the distractions that otherwise would aim for entertainment.
- The type of animations and visualizations used in educational videos are specifically designed to support learning of complex abstracts concepts.
- The mathematical explanations of explained ideas are explicitly included and explained as part of educational videos.
- They are often part of a wider series, allowing to link new contents to prior knowledge and creating a structured sequence of videos that increase in complexity.

With the development of the educational video category in the channel, also agreements with universities have taken place to produce specific videos or video series. A successful example would be the curricular integration strategy created together with *Universitat Politècnica de Catalunya* to reinforce Electromagnetism and 3-Phase Circuits concepts in "Electrical Machines I" subject within the Electrical Engineering BSc. Such initiative constituted a real classroom experience covering ERL and post-ERL stages, and the impact of videos was evaluated as a mitigating measure for such an unprecedented learning environment [47].

After more than two years since reconceptualization stage, *Sígueme la Corriente* has become a singular case of a STEM YouTube channel with dual purpose towards dissemination and education. This presents the opportunity of comparatively analyzing the performance of both types of videos and understanding the factors driving their use.

1.3. Objectives and research questions

This study is aiming to provide an analysis on how a YouTube channel might evolve to satisfy the dual needs from the dissemination and education perspective in STEM disciplines, as well as the comparative performance of both types of contents. *Sígueme la Corriente* channel is the object of study, continuing from previous analyses about its potential educational value, as well as its integration in real classroom scenarios. These assessments motivated the creation of specific contents addressing pedagogical purposes, which have been

complementary to the dissemination contents regularly published in the channel.

Therefore, this research's main objective relies on deeply understanding the comparative performance of dissemination videos versus educational videos in the context of a STEM YouTube channel, as well as the factors influencing it. The whole operating lifetime of *Sígueme la Corriente* has been analyzed, covering a total timeframe of six years (from 2017 to 2022). As channel owners, authors counted on advantaged data that could not otherwise be mined by any third party, which allowed deeper data acquisition and analysis.

On the one hand, it would be interesting to evaluate to which extent is the channel being used for educational or dissemination purposes, in order to confirm if the educational use (initially assumed as secondary use of the channel) might have become its predominant use due to the new education-focused strategy. On the other hand, the detailed owner's information for this channel is considered valuable in further providing data-based evidence about video length relevance for both educational-aimed and entertainment-aimed contents, based on the retention rate. Analyzing this parameter, together with other influencing metrics for video popularity, this study intends to provide further empirical evidence complementing the previous analyses on the channel's audience perception about the main parameters to define a good quality video for education.

Therefore, this research intends to answer the following research questions:

- RQ1: Is the educational use of a STEM YouTube channel higher than the entertainment use?
- RQ2: Is video length determinant for video performance in both education and dissemination purposes?

After this initial introduction to relevant literature on video integration as pedagogical aid in STEM disciplines, Section 2 defines the methodology followed in this study. Section 3 presents the most relevant results from the channel's statistics gathered for its six years of activity, and Section 4 is intended to deeply analyze the implications of this study, how these results are related with literature and their main contributions. Section 5 highlights the main conclusions of this article and, finally, Section 6 presents the main limitations and future works of this study.

2. Materials and methods

The YouTube channel object of study is *Sígueme la Corriente*: a STEM channel focused on energy, electricity and sustainability. It has been operating since January 1st, 2017, up to December 31st, 2022, and a total of 147 videos have been published in it, reaching 146,772 subscribers and 4,268,071 views. An extended description of the channel, its scope and the characteristics of its videos is included in the Introduction.

The following subsections are aimed at deeply explaining the methodology of this study, in order that both reproducibility and replicability are ensured.

2.1. Data collection

The data for this study has been collected through a six-year period, during the whole operating lifetime of the channel (from 2017 until 2022). Data has been extracted from YouTube Analytics, accessible through *Sígueme la Corriente*'s YouTube Studio for owners [48]. This tool allows to extract all the relevant metrics for videos published in the channel throughout its whole lifetime. However, even though YouTube Analytics is limited to videos as subjects of study, gathered data is representing the global use of the channel across its more than 4 million accumulated views. Moreover, counting on owner's data of the channel has allowed to perform a deeper and more accurate analysis than it would have been possible with publicly available data or through data mining. Additionally, it allows to obtain a more focused and detailed analysis of correlations between the most relevant video metrics, to understand which are the variables most influencing user engagement.

These data are available in any YouTube channel to their respective owners, and can be extracted from YouTube's content management system through YouTube Studio, under the section statistics. Within such section, any owner can select specific information on any video's performance, as well as on the channel. Moreover, advanced statistics are also available for several variables, allowing the owner to set up the time period for which the statistics will be extracted and also exporting them to an.csv file that will serve as raw data for analysis.

The sample considered for this study consisted of 147 videos, which represents the total number of videos published in the channel under the three categories pre-established due to intentionality: educational, dissemination and others (please, refer to the Introduction for more information). All the videos considered in this study were originally created by *Sígueme la Corriente* and published in the channel, excluding any content from third parties that might be present in certain playlists (e.g., interviews in tv programs or collaborations in other channels). The information collected for all videos has allowed to obtain a contextual understanding of the main metrics' evolution through time.

Particularly for the case of demographic information, whereas the geographic distribution of users in countries has been available for the whole period covered in this study, in the case of cities it has only been available since August 19th, 2021. Therefore, results for this parameter will only be shown as additional contextual information only for a fraction of the studied period. This fact has been addressed in the Limitations section.

Regarding the comparative study, the two video categories considered as object for comparison were educational and dissemination. Whether "others" category contributed to the overall statistic analysis of the channel, for comparisons between generic dissemination contents and contents designed for educational purposes, a subset of 91 videos has been considered, excluding in these cases the 56 videos categorized as "others".

Finally, comments received in the channel have not been collected for their assessment through qualitative methods. This could be an interesting complementary research analysis to be developed as continuation of this study and is, therefore, declared in Limitations and Future Works.

The collected information is available online through Mendeley Data, where it can be accessed and downloaded (Appendix A).

2.2. Available and analyzed variables

When accessing to the advanced mode of the Analytics section of YouTube Studio for owners, a series of parameters are made available that are useful to evaluate the performance and use of a channel. These metrics are grouped in several concepts, as shown in the following list:

- Overview: watch time (hours), views, average view duration, average percentage viewed, subscribers, videos added, videos published.
- Reach: impressions, impressions click-through rate, shown in feed, viewed (vs. swiped away), unique viewers, average views per viewer, new viewers and returning viewers.
- Interactions: subscribers gained, subscribers lost, likes, dislikes, likes (vs. dislikes), shares and comments added.
- Playlists: playlist watch time (hours), views from playlist, playlist average view duration, playlist average percentage viewed, playlist starts, playlist exits, playlist exit rate, average time in playlist, views per playlist start and playlist saves.

Moreover, additional metrics are available referred to concepts that are not deemed relevant in this study, such as revenue, members, posts, cards, clips, end screens, live contents, remixes, shopping and YouTube premium.

From all available metrics, this research focuses mainly on a selection of the most relevant parameters for the study's scope. They are grouped in Results section as those referring to reach and awareness (i.e., impressions, views and subscribers), use (average view duration) and interaction (comments, shares, likes and dislikes). Additionally, video length and video categories set up by intentionality are also considered as pre-defined parameters not depending on the channel's use. And, finally, contextual variables are considered such as the demographic information of users (gender, age, countries and cities) and the device type used when consuming the channel's contents.

2.3. Data analysis

Statistical analyses shown in Results section have been performed using Jamovi [49,50], with a confidence level of 95 % in all cases. Normality Shapiro-Wilk test concludes that the distribution of the data gathered is non-normal and, therefore, non-parametric statistics should be considered.

A quantitative approach has been developed for this non-experimental research, distributed between two main stages: observational and correlational. On the one hand, the observational stage is aimed to understand the general evolution of the channel, focusing on metrics such as views distribution, demographic characteristics, and consumption habits. Descriptive statistics have been useful to analyze and represent relevant explanatory information about the channel's users (demographic characteristics and device type used), as well as the overall channel's performance on the targeted metrics. Moreover, considering the non-normal distribution of variables for observational analysis, Mann-Whitney *U* has been used to detect significant differences in the studied variables among education and dissemination categories. Finally, the geographical distribution of visits has been analyzed using QGIS [51], which has also allowed to create countries and cities maps for their representation. On the other hand, the correlational stage aims to detect clear links between the different variables that measure videos' performance, to detect which patterns are definitory for video consumption, and also potential differences between dissemination and educational contents. Due to the non-normal distribution of most variables, Spearman's correlation analyses were used aiming to find significant relations among relevant metrics defining videos' performance, as well as different consumption behaviors between both types of contents, which might be useful when extrapolating those results to the broader picture of educational YouTube channels for STEM disciplines. Additionally, particularly for the parameter of average view duration (%) normality has been confirmed, which allows to perform linear regression analyses in such case.

In terms of data curation, the only manipulation that has been performed in the raw data file prior to the data analysis is the incorporation of videos' category and duration as an additional pre-set variable that allows grouping videos by their intentionality (educational, dissemination or others). The rest of the information has been directly extracted from the raw data file provided by YouTube Studio Analytics. All the information used in this study is available online through Mendeley Data (Appendix A).

3. Results

In this section, results are presented as per the previously stated stages of the study: observational and correlational. This information is intended to provide a complete mapping of the use of a STEM YouTube channel with both educational and dissemination contents. These analyses are also aimed to enhance the specific knowledge about the performance of education-focused videos in the context of STEM dissemination channels, intending to provide teachers and professors with valuable information to foster videos' pedagogical integration.

3.1. Observational analysis

Within the observational stage, the information is presented on key metrics for the performance analysis of any YouTube channel, such as views distribution, demographic characteristics, interaction with videos, or consumption habits. From those metrics, one of the most relevant parameters for the evaluation of a YouTube channel's performance is "views", as it is representative of the number of times that a video has been played. Fig. 2 represents the distribution of views throughout the whole lifetime of the channel. Additionally, a representation of the aggregate views is incorporated so that the channel's growth on popularity could be easily appreciated. In the six years lifetime of the channel, it has achieved a total of 4,268,071 views. In addition to these metrics representing the overall use evolution of the channel through time, subscribers' evolution can be seen in Fig. 3.

The channel's performance in terms of views and subscribers is also showing the effects of the three different stages presented at the Introduction section: presentation, consolidation, and reconceptualization. These stages correspond to a clear evolution in the management and content strategies of the channel, and their effect can be appreciated in the dotted trend lines included in Fig. 2. The channel has experienced a remarkable increase in views, subscriptions, and use since the reconceptualization stage began in August 2020. From such date, the specific series of educational videos started to be considered as half of the proportion of videos published, counting with optimized features for their use as pedagogical aid.

Views and average percentage of view duration are presented in Table 1, distributed per age range. The use of *Sígueme la Corriente* is mainly centered in people between 18 and 34 years old, covering 57.37 % of views. Additionally, referring to gender distribution, 84.12 % of views have come from men and 15.88 % from women. But besides views count, the percentage of video that is reproduced is also a very interesting parameter to understand audience retention through the channel contents. The average view duration on the channel is very similar for all age ranges, covering from 34.95 % to 41.29 %. When considering all video views during the whole lifetime of the channel, the view duration is in average 49.87 % of the total length of videos.

In terms of geographical distribution, most visits come from Spain, Mexico, and Argentina, with respective 24.50 %, 22.14 % and 11.48 % of total views. Furthermore, when analyzing views per cities, the main sources are Lima (Perú), Madrid (Spain) and Santiago (Chile) with respective 34.45 %, 17.14 % and 8.69 %. Data for cities has recently been implemented in YouTube Studio and, therefore, it is limited to the period between September 2021 to December 2022. Maps shown in Fig. 4 represent the whole geographical distribution of visits, highlighting the 10 countries and cities that are most relevant when it comes to views share. Additionally, further information for top 10 countries and cities is included in Table 2.

When deeply analyzing the sources of views, interesting information arises. First, 78.78 % of total visits comes from non-subscribers, which shows a wide sporadic use of the channel that might be associated with queries or occasional support. Additionally, the main device type from which the channel is consumed is the mobile phone, covering 53.92 % of views. Table 3 shows how views are distributed by device type, as well as the average view duration in each kind of device. While computer represents 19.04 % less views than mobile, it is noteworthy that viewers stay an 8.1 % longer watching the channel's videos. The highest retention rate is found in television, with a 57.4 % of average view duration.

Furthermore, an analysis of view sources can also bring interesting information on how *Sígueme la Corriente* is used. Up to a 41.64 % of the channel's traffic comes from specific searches, with values of 24.32 % and 17.32 % respectively coming from YouTube search and exploration function. Another 28.22 % of the traffic comes from suggested videos section, and 13.03 % of views comes from external sources. In terms of internal traffic, a 5.59 % of views comes from the channel pages, and 1.27 % and 1.11 % comes respectively from playlists and notifications.

While previous results consider the bulk statistics of all the channel's contents as contextualization, this paper mainly intends to compare the performance of educational videos versus dissemination videos. Table 4 summarizes the mean values for key metrics in both types of contents throughout the whole channel's lifetime. Additionally, Mann-Whitney *U* tests have been performed through all

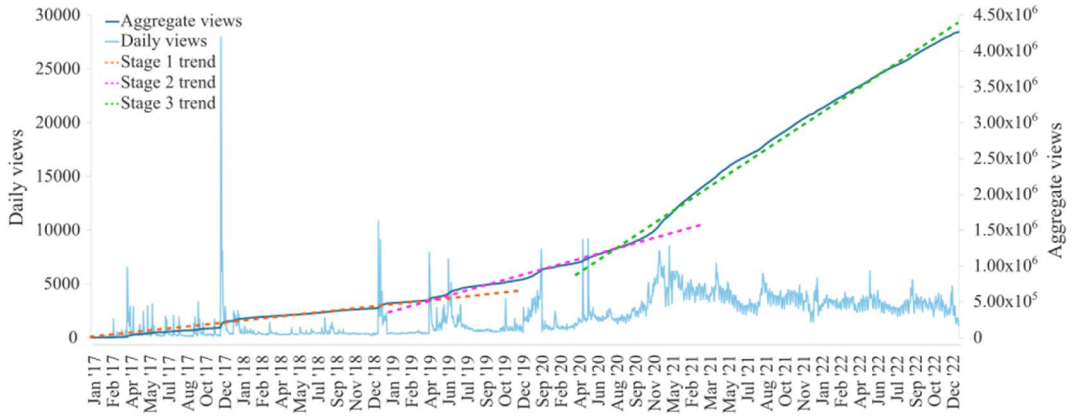

Fig. 2. Daily and aggregate views during the whole channel's life, showing in dotted lines its three definitory stages: presentation (orange), consolidation (pink), and reconceptualization (green). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

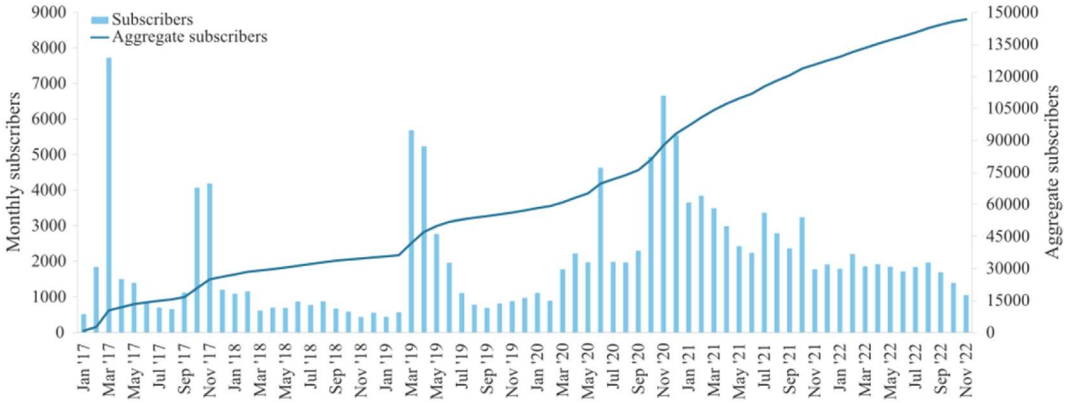

Fig. 3. Monthly and aggregate subscribers during the whole channel's life.

Table 1
Views distribution and average view duration per age.

Age of viewer	Views (%)	Average view duration (%)
Between 13 and 17 years old	2.61	34.95
Between 18 and 24 years old	28.76	38.73
Between 25 and 34 years old	28.61	41.29
Between 35 and 44 years old	17.66	40.33
Between 45 and 54 years old	12.05	40.36
Between 55 and 64 years old	6.81	39.7
More than 65 years old	3.5	39.1
Total	100	39.21

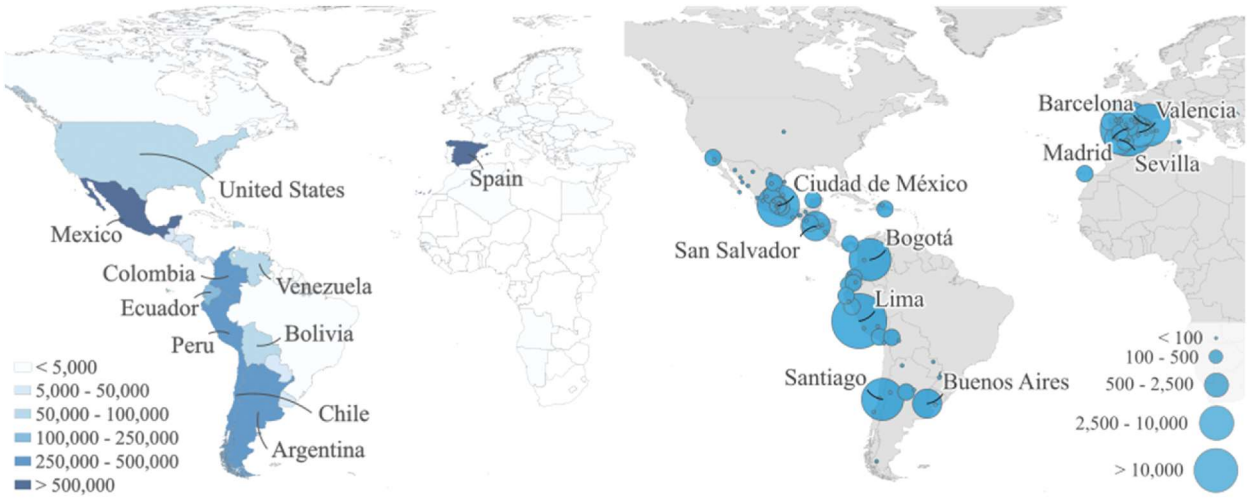

Fig. 4. Geographical distribution of views. Left: views per countries from January 1st, 2017, to December 31st, 2022. Right: views per cities from September 1st, 2021, to December 31st, 2022.

metrics, considering as null hypothesis that there is no significant difference between the mean values of education and dissemination video categories.

As shown in Table 4, there is no significant difference in average video length between educational and dissemination videos published in the channel, which is between 5 and 15 min for 69 % of the educational videos and 63 % of the dissemination videos.

Regarding the number of views, there is indeed significant difference between both categories. Those contents that are created aiming at educational use achieve in average 2.78 times more visits than dissemination contents. Additionally, view duration reveals respective average retention rates of 47 % and 42.3 % of videos' length for education versus dissemination. Similarly, educational videos receive in average 2.89 times more comments compared to dissemination contents. The sharing rate is also a very useful parameter to identify the use of the channel. There are significant differences in the number of shares when comparing both categories,

Table 2
Geographical distribution of views for the top 10 countries and cities.

Views per country		Visits per city	
Country	Views	City	Views
Spain	973,204	Lima (Peru)	22,656
Mexico	879,599	Madrid (Spain)	11,272
Argentina	456,186	Santiago (Chile)	5717
Peru	346,910	Bogotá (Colombia)	4945
Colombia	345,147	Ciudad de México (Mexico)	4857
Chile	271,014	Barcelona (Spain)	2811
Ecuador	132,744	San Salvador (El Salvador)	919
United States of America	96,190	Sevilla (Spain)	825
Bolivia	89,125	Buenos Aires (Argentina)	817
Venezuela	75,901	Valencia (Spain)	634

* Views per countries cover from Jan 1st, 2017, to Dec 31st, 2022. Views per cities cover from Sep 1st, 2021, to Dec 31st, 2022.

Table 3
Views distribution and average view duration per device type.

Device type	Views (%)	Average view duration (%)
Mobile phone	53.92 %	36.20
Computer	34.88 %	44.30
Television	7.06 %	57.40
Tablet	4.13 %	46.10

Table 4
Channel metrics mean values per content category, and comparison between Education and Dissemination categories.

Metric	Education		Dissemination		Education *vs* Dissemination[a]	
	Mean	SD	Mean	SD	*U*	*p* value
Video length (s)	723	442	818	344	692	0.079
Views	72,934	63,782	26,337	29,703	352	< **0.001**
Average view duration (%)	47	13.5	42.3	10.5	662	**0.044**
Comments	180	356	62.2	57.2	518	**0.001**
Shared	1234	1151	329	393	292	< **0.001**
Like	3788	3376	1181	1066	315	< **0.001**
Dislike	45.1	41	36	54.7	609	**0.014**
Subscribers	2007	2358	425	721	307	< **0.001**

Bold values: $p < 0.05$.
[a] Mann-Whitney *U* test.

where education contents are shared 3.75 times more. Similarly, educational videos achieve 3.2 times more likes than dissemination videos. A difference in dislikes is also found, where educational videos receive 1.25 times more dislikes than dissemination videos. Additionally, educational videos achieve 4.72 times more subscribers for the channel than dissemination videos.

As per the whole channel's collected data, Fig. 5 represents the relative video views and playlists starts distribution considering the total number of videos in each category. The views associated with educational contents in *Sígueme la Corriente* represent a 67 % of the total 4,268,071 views of the channel. Additionally, the contents are distributed through playlists that help users find the type of videos that they are seeking. These playlists are distributed both thematically and by purpose, facilitating their categorization also into education and dissemination. As shown in Fig. 5, from all playlists started in the channel, education playlists represent a 73 %.

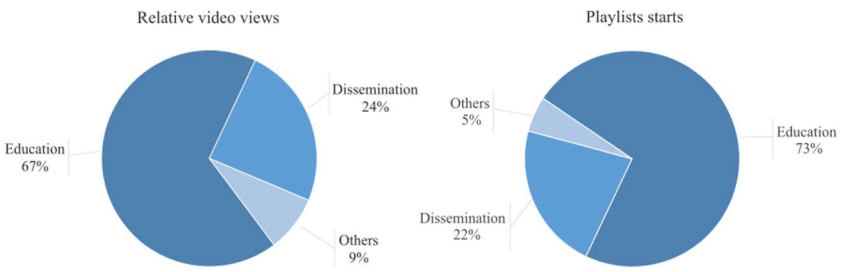

Fig. 5. Relative video views and playlists starts distribution per content category.

3.2. Correlational analysis

Intending to find deeper links among the analyzed variables for both contents' categories, non-parametric Spearman's correlation tests have been performed. This analysis aims to detect whether there are significant correlations between key metrics, and whether those correlations are valid for both education and dissemination categories. The results of the tests are presented in Table 5, from where interesting information can be extracted.

First, as evidenced through these results, views are not related with video length nor view duration achieved by the channel's contents. However, this metric is deeply related with impressions, which is the number of times that YouTube shows the content to potential users (after searching for similar topics, in the side bar of related videos, or at YouTube's main page). The more visible a content is, the more visits it gets. Additionally, interaction parameters as comments, sharing, likes and dislikes, are correlated with visits equally both for education and dissemination contents. This is also coherent with the fact that all the interaction parameters are correlated with each other, as they rely on the number of views and are representative of a coherent behavior: when the channel's contents are more viewed, interaction increases in the form of comments, sharing and likes or dislikes. As subscriptions to a channel is the maximum representation of loyalty and fan-phenomena, we can also appreciate how the number of subscribers is related not only to views, but also to other interaction metrics as the last stage of the user's attachment to the channel's activity.

Video length is one of the most relevant parameters when defining the characteristics of a video. When performing an optimized explanation, it is the result of how complex a topic is, together with the depth of the explanation provided. As mentioned earlier, most of *Sígueme la Corriente*'s videos are framed between 5 and 15 min long, representing 65 % of videos under both education and dissemination categories. Video length, as a parameter, is correlated with view duration for both categories, following an inverse relation as shown in Fig. 6: the more a video lasts, the less percentage of the video is viewed. Regression lines represented are defined by equations (1) and (2) respectively for education and dissemination. Both lines' intersecting point is the video length for which the mean retention rate is the same in both categories, resulting in 16 min and 29 s for a 40.21 % of video length viewed in average. As can be easily appreciated in the slopes, dissemination videos are less dependent on length, compared to educational videos. Educational videos' regression line shows a more aggressive slope, providing a clear idea on how, in this category, audience retention is more susceptible towards video length. It is also noticeable how dispersion is lower in educational videos, potentially responding to a more

Table 5
Values of Spearman's correlation rho among the main variables of interest, per content category.

	Video length	Views	View duration (%)	Impressions	Comments	Shared	Like	Dislike	Subscribers
Video length	–								
	–								
Views	0.285	–							
	0.095	–							
View duration (%)	-0.852**	-0.055	–						
	-0.551**	-0.098	–						
Impressions	0.481*	0.949**	-0.221	–					
	0.180	0.910**	-0.039	–					
Comments	0.533*	0.885**	-0.215	0.920**	–				
	0.203	0.830**	0.098	0.861**	–				
Shared	0.089	0.921**	0.140	0.849**	0.763**	–			
	0.203	0.920**	-0.081	0.911**	0.825**	–			
Like	0.380*	0.957**	-0.074	0.975**	0.917**	0.894**	–		
	0.112	0.905**	0.132	0.912**	0.915**	0.923**	–		
Dislike	0.230	0.965**	0.005	0.904**	0.865**	0.903**	0.912**	–	
	0.174	0.875**	-0.110	0.856**	0.817**	0.809**	0.809**	–	
Subscribers	0.362	0.974**	-0.078	0.963**	0.918**	0.881**	0.969**	0.949**	–
	0.111	0.957**	0.047	0.922**	0.870**	0.926**	0.947**	0.848**	–

Dark blue: education category. Light blue: dissemination category.
*p<0.05; **p<0.001

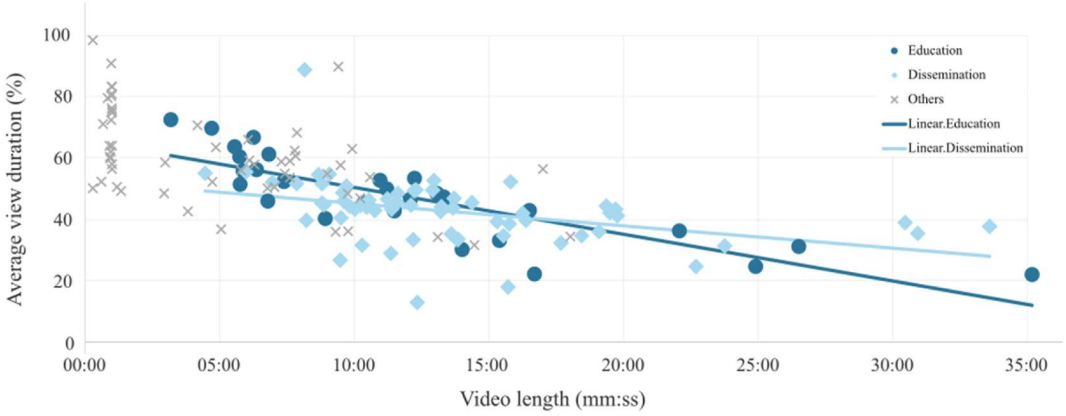

Fig. 6. Linear regression between video length and view duration per content category.

consistent user behavior due to such contents' specific common characteristics to optimize their potential pedagogical use.

$$y = 65.255 - 0.0253x \tag{1}$$

$$y = 52.190 - 0.0121x \tag{2}$$

However, there are additional interesting differences in user behavior for both categories when considering video length. There is a significant positive correlation between video length and impressions, comments and likes for educational videos, and this fact is not verified for dissemination videos as shown in Table 5. This means that longer educational videos published in the channel tend to have more impressions and more interaction in the form of comments and likes. Therefore, even though longer educational videos are watched in average through a shorter percentage of their duration, potentially because they are for a narrower target audience, they are greatly appreciated and interacted with.

4. Discussion

Over the last decade, YouTube has asserted its dominance as the main video-based social network and, therefore, as the most used network in university education for video-aided learning [1,7]. However, there are still some challenges mainly related to the adequate selection of quality videos as pedagogical aid due to the massive quantity of videos uploaded to the platform and the popularity-driven search criteria [35,36]. This article intends to comparatively evaluate the performance of education-focused contents and videos designed for social dissemination that might be introduced in learning activities without a specific focus for such use. For this purpose, owner's data have been used from a popular STEM YouTube channel called *Sígueme la Corriente*.

First, an observational analysis has provided useful contextual information from the overall channel characterization. Both the channel's presentation and consolidation stages described at the Introduction, and characterized in Fig. 2, had allowed the achievement of a total quantity of 69,829 subscribers and 1,180,848 views by July 31st, 2020, after three years and seven months of activity. The reconceptualization stage proposed the creation of different series of videos specifically aimed for pedagogical use in tertiary education, which brought the channel to a whole other level during the following two years and five months. This additional format, together with the dissemination videos that continued being published, contributed to the channel's acquisition of new 76,943 subscribers and 3,087,223 views leading to the total 146,772 subscribers and 4,268,071 views quantified in this study. This means that 52 % of subscribers and 72 % of views were gained during reconceptualization phase, which lasted 32.5 % less time than both presentation and consolidation phases.

Overall, the average number of views per video in *Sígueme la Corriente* is 28,965, and the median is 10,202. Considering the context, the median views count achieved by a YouTube video is 89, and average YouTube videos tagged as Science and Technology achieve a mean count of around 6638 views [3]. Moreover, YouTube channels achieve in average 199 subscribers and 43,000 views. This information allows us to comparatively consider *Sígueme la Corriente* as a popular Science and Technology YouTube channel.

During these years an increment of women presence in the channel's audience has also been quantified. During the first year of the channel's activity, only 6 %–9 % of the audience were women. This percentage has increased during reconceptualization stage, to the 15.88 % of women viewers that was quantified until December 31st, 2022. This is a positive result, also in consonance with the findings from Saurabh and Gautam [9] whose channel's audience is composed by a female share within the range of 20–30 %. They highlight the fact that female distribution on their case is between 13 and 24 years old, which might imply that young women are progressively getting more involved in STEM education. Yang et al. [3] also highlight a similar situation in their study, concluding that the 18–44 age group and males were the most active and engaged demographic group. This is in consonance with other research concluding that males are more active audiences in online science social media [52]. At this point it is also relevant to highlight that there is a clear gender gap among edutubers that implies fewer presence of role models for women, which might influence their interest in this platform as source of information for STEM education [3,53,54].

Geographically speaking, the channel's language is determinant for its audience to be mainly based in Spanish-speaking countries. The main countries reproducing its contents are Spain, Mexico and Argentina, representing respectively 22.8 %, 20.61 % and 10.69 % of total views. Additionally, up to 57.37 % of the channel's viewers are between 18 and 34 years old, aligned with the cases described by Bello-Bravo et al. [43], Reina et al. [55] and Yang et al. [3]. The average retention rate in terms of video duration percentage is very similar among all age ranges, reaching 41.29 % in the better case.

Referring to the device types where the channel's contents are consumed, *Sígueme la Corriente* is mainly used in mobile phones and computers, with a respective representation of 53.92 % and 34.88 % of total views. In terms of retention rate, phone and computer views achieved respectively in this channel a 36.20 % and 44.30 %. The case described by Saurabh and Gautam [9] represents the opposite situation, where computers represent an 81 % of their audience preferred device, and mobile phones only achieved a 16 %. Yang et al. [3] also received 81.32 % of their visits from computers and mobile phones with respective 64.01 % and 59.88 % retention rate.

Views from searches, external sources and suggested videos cover up to 82.89 % of the traffic, which is also aligned with the fact that 78.78 % of views comes from non-subscribers. The main view sources in the channel are represented by suggested videos and YouTube search covering respectively 28.22 % and 24,32 % of the channel's traffic. The exploration function and the external sources are covering 17.32 % and 13.03 % of the channel's traffic. This is supported by Cheng et al. [56] explanation that external sources are highly important in videos' early stage, where social referral during the first week creates awareness and provides the initial views boost. Our results are also aligned with Saurabh and Gautam's [9], whose channel's main view sources also were YouTube search and suggested videos with 39 % and 18 % of views. In their case, also 13 % of visits came from external links. Also, Yang et al. [3] reported that the majority of their scientific communication channel's users were non-subscribers, with a 92 % of representation. Evidence points out that STEM dissemination channels tend to engage mainly with external audience, which implies that the use of these channels is mainly sporadic and might be associated with queries or occasional support.

However, though these metrics are interesting to know the overall performance of the channel and the main characteristics of its audience, it is not easy to know whether such use is related to satisfy educational needs or whether it is related to entertainment and curiosity-satisfaction purposes. Reconceptualization stage in *Sígueme la Corriente* has also led to an increase in other interaction parameters, such as comments, shares, likes and dislikes, which might provide interesting information in user behavior and use of the educational and dissemination contents provided by the channel. The following subsections intend to dig deeper into this issue, by presenting a direct comparison of education and dissemination contents' performance, aligned with the two research questions presented in this article.

4.1. RQ1: is the educational use of a STEM YouTube channel higher than the entertainment use?

As means to answer this research question, we will consider that the use of a YouTube channel is mainly described by views, average view duration, subscribers count and interaction parameters (comments, shares, likes and dislikes). In this regard, in the case of *Sígueme la Corriente*, educational contents are by far more viewed and interacted with. Additionally, this study confirms the significant correlation between awareness metrics and interaction metrics, meaning that impressions, views, and subscribers metrics are correlated with comments, shares, likes and dislikes. This is consistent with the common consensus in literature [43,57–59].

Both the significant difference in the average view duration of educational videos compared with dissemination videos, and the number of views that each category has achieved, are representing a predominant educational use of the channel. Up to a 67 % of the video views achieved, in relation to the total number of videos published under each category, are related to educational contents. Moreover, a 73 % of playlists starts in the channel refer to playlists created for educational use.

The interaction parameters (comments, shares, likes or dislikes) have also experienced a trend change after August 2020, which might be related to the effects of the reconceptualization strategy followed in the channel. This stage included the creation of a specific series of educational videos considering pre-defined criteria to enhance videos use for pedagogical purposes. Such criteria are explained in more detail at the Introduction section. There are also significant differences in these interaction metrics between both education and dissemination categories.

Regarding comments, the channel has received an average of 4.95 comments per day, but there is a clear tendency change from August 2020 on, where a mean value of 7 comments per day was achieved, compared to presentation and consolidation stages (average value of 3.49 comments per day). The peak of comments received was 149 on December 3rd, 2020. There are 2.89 times more comments in educational videos than in dissemination videos (average of 180 *vs* 62.2 comments per video), which might represent a greater willing of asking questions or sharing perceptions with the video creator and with pairs in the case of the pedagogical use.

Shares show a similar pattern, with a mean value of 6.8 video shares per day during presentation and consolidation stages, and an average of 54.67 shares per day during reconceptualization stage. In the case of shares, the peak value was 232 on November 25th, 2020. Educational videos are shared in average 3.75 times more than dissemination videos (1234 *vs* 329 shares in average), which not only represents a higher use of educational videos, but also a greater willing to share them with others (e.g., colleagues, students, teachers, etc.).

Likes and dislikes are also confirming the higher use of the educational videos published in the channel. During the presentation and consolidation phases, the channel received respective averages of 58.03 and 1.27 likes and dislikes per day, where the reconceptualization stage changed the tendency to respective mean values of 160.15 and 2.77. Education contents received 3.2 times more likes than dissemination videos. Additionally, they have also received a mean of 45.1 dislikes per video, which is higher than the average of 36 dislikes per video quantified for dissemination contents. The reason behind this apparent contradiction is the high exposure of educational videos, which are more visited and consumed. Even though educational contents are visited 2.78 times the

number of visits achieved by dissemination contents, they only get 1.25 times more dislikes. Therefore, in proportion, educational contents receive fewer dislikes-per-visit.

Unlike other parameters such as comments or visits, likes are directly representing a positive evaluation of the audience about the videos' contents and format [60]. Videos with more likes use to receive more visits, and these tend to have longer average view duration, as has been demonstrated in this article. These results are also coherent with the findings of Yang et al. [3]. Previous research also highlights that, in social media environments, contents with higher number of likes are watched earlier by users and during more time [61]. Moreover, an interesting analysis of the reasons to like or dislike a video was developed by Shoufan [18], who performed a qualitative analysis on 51 students' responses about 54 videos. He found that those reasons correspond to the videos' performance on the following 7 main clusters or parameters (presented in order of impact): explanation and understanding, technical presentation, content, efficiency (worthiness of time spent watching the video), language and voice, interest, or others. This is coherent with the high rate of likes achieved in *Sígueme la Corriente*, whose users' perception on similar metrics has been previously quantified [45]. With a sample of 912 users, it was concluded that the channels' contents are helpful to understand topics of interest (4.58 score over 5), the images and animations used to understand concepts were considered adequate (91.7 % positive responses), the technical level of the videos was considered adequate (91.6 % positive answers), the rhythm of the videos was adequate for concept comprehension (92.5 % positive answers), the presenter's communication abilities were found attractive and interesting (95.6 % positive responses), and the topics and contents selected were considered interesting (82.4 % positive answers).

Regarding subscribers, the channel receives an average of 67.14 per day. Educational contents are responsible in average for 4.72 more people subscribing to the channel than dissemination contents. This means that a mean value of 2007 subscribers have been achieved from each educational video, versus 425 from each dissemination video.

As presented, there is a clear preference towards the use of educational contents from *Sígueme la Corriente* over the use of regular dissemination contents. This implies that the perceptions quantified from the channel's users in previous exploratory analyses was pointing in the right direction. Covering both presentation and conceptualization phases, the initially involuntary use of the channel's dissemination contents for educational purposes was evidenced, as well as an overall positive perception of such contents [45]. Additionally, a qualitative analysis with 524 participants was conducted in the same time frame [46], where *Sígueme la Corriente*'s audience highlighted the channel's value for understanding and learning complex concepts in electrical engineering, claiming that it also enhanced their motivation and interest towards such discipline. Responding to such demands, reconceptualization phase has addressed the unveiled educational needs of the audience, and the contents resulting from such considerations have performed much better than the classic dissemination format offered by the channel.

This preference for contents designed to be compatible with an educational use could be of relevance for other content creators, as they show how STEM YouTube channels might be perceived as suitable for educational use. Moreover, it also highlights how fostering contents specifically designed for educational use could boost the channel's growth, considering their curricular alignment and their format adaptation to be consumed as pedagogical aid.

4.2. RQ2: is video length determinant for video performance in both education and dissemination purposes?

Video length is a key parameter when planning to create and consume a YouTube video. In the early stages of YouTube, regular users were only authorized to upload videos up to 10 min length [62]. And even though nowadays there is no length limit imposed by the platform, results suggest that the longer an educational video is the more impressions it gets. Which is to say that such video is shown by YouTube to a wider potential audience in the search for similar topics, in the side bar of related videos, or at YouTube's main page. This is aligned with previous research stating that longer videos are more likely to be recommended by YouTube [3].

However, even though results point to an increment in impressions for longer videos, no correlation has been found in *Sígueme la Corriente* between video length and views count. In contrast with these results, there are some authors that claim that video length is a parameter influencing video views. This is indeed expressed by Cheng et al. [62] and Yang et al. [3], finding significant correlations between those parameters. Saurabh and Gautam [9] also highlight as a result that video length influences views count, but in their case no correlation analysis is presented. As a hypothesis, a possible explanation is that the type of videos analyzed in *Sígueme la Corriente* are mainly used for a utility purpose (either being educational or for curiosity satisfaction), and while videos might be recommended from YouTube they will only be accessed when there is a specific utility behind. Moreover, most authors agree that shorter videos are often preferred by the audience over longer ones. This might also be a factor influencing the decision of not reproducing *Sígueme la Corriente*'s longer videos recommended by the platform. Hence, video length would increase YouTube's recommendations and, therefore, impressions, but this does not necessarily mean that users decide to watch the videos.

The reasoning behind user preference over shorter videos includes that they are found more engaging, they are associated to an increasement of learning outcomes, and they are also influencing students to use them more than once for educational purposes [14–17,63–65]. But this is not only a matter of shortening a video, rather than also considering an adequate efficiency in explanations [18]. However, it is important to understand how short a video should be to take advantage of these positive effects in educational environments. This implies the consideration that an optimal target of video length should be flexible within certain margins, as it needs to adapt to the complexity and extent of explained concepts.

In terms of video length, the majority of *Sígueme la Corriente* videos are between 5 and 15 min, depending on the contents' requirements for a complete and clear explanation. This is real for 69 % of the educational videos and 63 % of the dissemination videos. During their creation process, particularly for educational videos, content delivery optimization is a target criterion. In fact, previous analyses in the channel suggest that its users perceive the channel's videos' duration as adequate, with a frequency of 88.4 % of positive responses [45].

Even though no correlation has been found between video length and the number of views in this channel, there is significant correlation between video length and the average duration of views. This implies that, in our case, video length influences how long does the audience stay in a video and, therefore, the potential success of its educational purpose. As described by the inverse correlation, the less a video lasts, the more percentage of the video is watched in both educational and dissemination contents. This is also true for Yang et al. [3] research, where correlation was found between video length and average view duration. Moreover, Bello-Bravo et al. [43] highlight this parameter of retention rate as a rather literal measure of viewer engagement. Regarding this metric, Fig. 6 shows that the average view duration in the channel for most educational videos between 5 and 15 min long is still above 50 % of video length.

It is important to mention that the educational contents are more sensitive to video length than dissemination contents. This fact can be appreciated in the regression lines defined by equations (1) and (2) respectively for education and dissemination. A possible explanation could be that educational videos are directed to a more specific use to explain concrete concepts or provide concise descriptions. In this line, it is also worth mentioning that educational contents show less dispersion in the linear regression model than dissemination contents. This is potentially due to the specific common characteristics present in all the educational contents of the channel, as opposed to the dissemination contents. In this last case, the format of the videos might change between each other as means of serving curiosity-satisfaction and entertainment purpose (as well as optimizing videos' reach in each particular topic). In opposition, educational videos in the channel prioritize a common format, pursuing curricular alignment, deeper focus, efficient explanations, enhanced quality of animations and visualizations, and back up mathematical explanations.

This is aligned with empirical results from Abu-Taieh et al. [23], which through structural equation modeling showed how the academic achievement through YouTube videos is influenced by the information adoption from YouTube as learning tool. Subsequently, the information adoption is influenced by the information usefulness, which might be linked with the utility perspective being satisfied through efficient explanations, as previously discussed. They also describe how the information usefulness is influenced directly from information quality, whereas the information language has not been evidenced as an influencing factor.

However, careful considerations should be taken when examining the inverse correlation between the video length and the retention rate. Even though regression lines appear to point to the reasoning that the shorter the better, video length should not be shortened to an extent that the contents presented are not adequately explained. This is also linked to the previously mentioned factor of the information quality. Therefore, video performance in terms of retention rate becomes a matter of the efficiency of the explanations, and this is a parameter highly valued for the educational use of videos. This fact has also been highlighted by Shoufan [18]. These results are aligned with DelSignore et al. [65] appreciations after an analysis of 179 videos in a pediatrics YouTube channel, where most videos lasted between 6 to 10 min. Shorter videos possessed the higher view durations (36 %–54 %), while videos exceeding 11 min achieved only a 15 %–28 % view duration.

Guo et al. [15] findings are also consistent with this evidence. Their study was based on data from an online MOOC with 6.9 million video watching sessions in STEM subjects, where the median engagement time was at most 6 min regardless of video length. Videos of 9–12 min were watched less than 50 %, and videos from 12 to 40 min were watched less than 25 %. Opposed to such findings, Lagerstrom et al. [66] argues that the "6-min rule" presented by Guo et al., despite it might be useful in MOOC environments, does not capture video viewing behavior of students in standard college courses. However, they also appeal to the creation of shorter materials than the traditional 50- or 75-min lectures, referring to an optimal range of 12–20 min-length videos as a "rule of thumb".

These comparisons between YouTube and MOOC are illustrative due to the similarities of both environments and formats. In fact, some classic MOOC platforms such as the Khan Academy or edX have also hosted their videos on YouTube for their consumption as MOOC enabling material [15,67]. However, it should be noted that the engagement behaviors in MOOC videos should not be literally generalized to other openly available online videos. MOOC students, as pointed out by Guo et al. [15] are more likely to find self-motivation and, therefore, retention rate is expected to be higher. This might be related to the fact that MOOC contents are presented in a structured environment, as opposed to open YouTube videos, and they often require voluntary registration. Linked to this idea, Shoufan [68] also pointed out that YouTube videos are more likely to be interrupted due to the different watching behavior of students. Unlike MOOC students, who follow a predefined video curriculum, YouTube users are actively seeking out the most suitable videos for their needs.

According to our results, and contrasted with literature, video length is clearly influencing video performance in terms of retention rate, which is a definitory measure of video engagement. This is particularly noticeable in educational contents, where optimal video length appears to be approximately between 5 and 15 min long. And it is highly recommended that this target margin for video length is considering an adequate time dedication to clearly and efficiently present the topics set as objective for each video. While dissemination contents also show a similar pattern, retention rate in their case is not so sensitive to video length.

5. Conclusions

STEM dissemination videos published on YouTube present an opportunity for teachers to use quality material as educational resources. However, the successful search and integration of "good quality" videos for education is challenging and not always easy. This research is considering the incorporation of a specific educational focus to already available STEM YouTube channels, which might benefit both teachers and content creators. In the first case, teachers can be benefitted by the increase of quality materials available, already optimized for their pedagogical integration. In the second, content creators can reap benefits from catering to this need by expanding their reach to a new audience segment and diversifying their channel's purpose (while maintaining its core social dissemination purpose). This diversification might bolster the channel's appeal and use.

A six-year data-driven analysis has been presented in this study for *Sígueme la Corriente* STEM YouTube channel based on owners'

data. Through this time frame, the channel has evolved from a purely STEM dissemination purpose to a dual purpose towards both dissemination and education. The objective of this research has been focused on analyzing such evolution to understand the implications of this dual use, focusing on the comparative performance of both types of contents, and the factors influencing it.

Results have revealed how the educational purpose of the channel has boosted its performance. The use of the channel has widely increased due to the creation of contents specifically designed for their integration as pedagogical aid. Comparatively, this study shows how the educational use of a YouTube channel of these characteristics is significantly higher than the entertainment or curiosity-satisfaction uses commonly associated to YouTube as social media. Additionally, it can be concluded that video length is a relevant aspect in video engagement, where significant correlations have been found between video length and retention rate. In this context, educational contents have shown to be more sensitive to this aspect than dissemination contents.

These results support the suitability of incorporating a focused strategy on education to STEM dissemination YouTube channels. Under adequate creation criteria to optimize their adequacy for pedagogical integration, as well as their curricular alignment, this potential new workstream presents an interesting opportunity. Moreover, from the educational perspective, it may positively influence the selection of more suitable videos to be integrated as part of a defined pedagogical context. The development of digital competences and pedagogical knowledge is crucial for teachers' acceptance and integration of these resources, for which DigCompEdu and TPACK frameworks are of relevance.

6. Limitations and future works

Though this study has presented interesting results after the analysis of the detailed data collected through six years, it also has some limitations that should be addressed. First, within the analyzed period there were different ERL scenarios imposed by the lockdowns due to covid-19 pandemic in the various regions where the channel's audience is based on. This implied a global increase in the demand for online resources and, therefore, during such period the consumption pattern of the channel might have been affected. However, this limitation is also partially mitigated by the fact that the analyzed period covers from January 1st, 2017, to December 31st, 2022, which implies that pre-ERL during-ERL and post-ERL scenarios are being considered in this study. Other authors are encouraged to perform similar replication studies that allow to extract conclusions from other STEM channels. Moreover, additional real classroom interventions will be performed for the integration of *Sígueme la Corriente* in a context where no ERL is taking place. Therefore, the focus of the study could be placed on videos' impact itself on a normal scenario rather than the videos' ability to mitigate an unprecedented situation.

Second, no objective metrics or parameters have been collected to measure content and format adequacy. Data collected is useful to measure videos' performance and use, and previous studies are providing complementary information in users' perception on content and format adequacy of the channel's videos for potential educational purposes [45,46]. As mentioned, further integration of the channel in real classroom scenarios will be implemented, also considering placing objective measures such as visual fatigue to evaluate the effect of videos on students. Moreover, a longitudinal analysis will be put in place to adequately measure the impact of such videos in their conceptual learning and academic performance.

Other limitation refers to videos being compared in a period where they have had different life cycles. Not all videos were published at the same time and, therefore, the data gathered is covering different time ranges for each video. A minor limitation is also declared regarding the geographic distribution of users in cities, which information has only been available in YouTube since August 19th, 2021, and, therefore, is not covering the entire period of study for this research. However, this information is provided as a contextual complementary description, and no conclusions of the study are affected or biased by this limitation.

Additionally, the classification on educational and dissemination contents was set by intentionality, as expressed in Introduction and Methodology sections, and this might imply a limitation that should be considered in the interpretation of results. Also, comments included by users have not been analyzed through qualitative methods, which represents a clear research opportunity for future works. Comments are expected to provide additional explanations to the different uses of educational videos versus dissemination videos, as well as the specific user experience of an important fraction of the channel's audience.

Finally, as this article is based on a study case, all data collected and provided refers to only one STEM YouTube channel, which might not represent the global behavior of YouTube audience. We encourage other authors to develop replication studies with channel owners' data to confirm whether these results could be extrapolated to the whole situation of STEM dissemination videos on YouTube.

CRediT authorship contribution statement

Ruben Lijo: Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **José Juan Castro:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Conceptualization. **Eduardo Quevedo:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: The corresponding author is the creator of Sígueme la Corriente YouTube channel analyzed in the research, and this is what could enable the possibility of counting with owner's data as described in the article.

Other authors declare that they have no known competing financial interests or personal relationships that could have appeared to

influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e24856.

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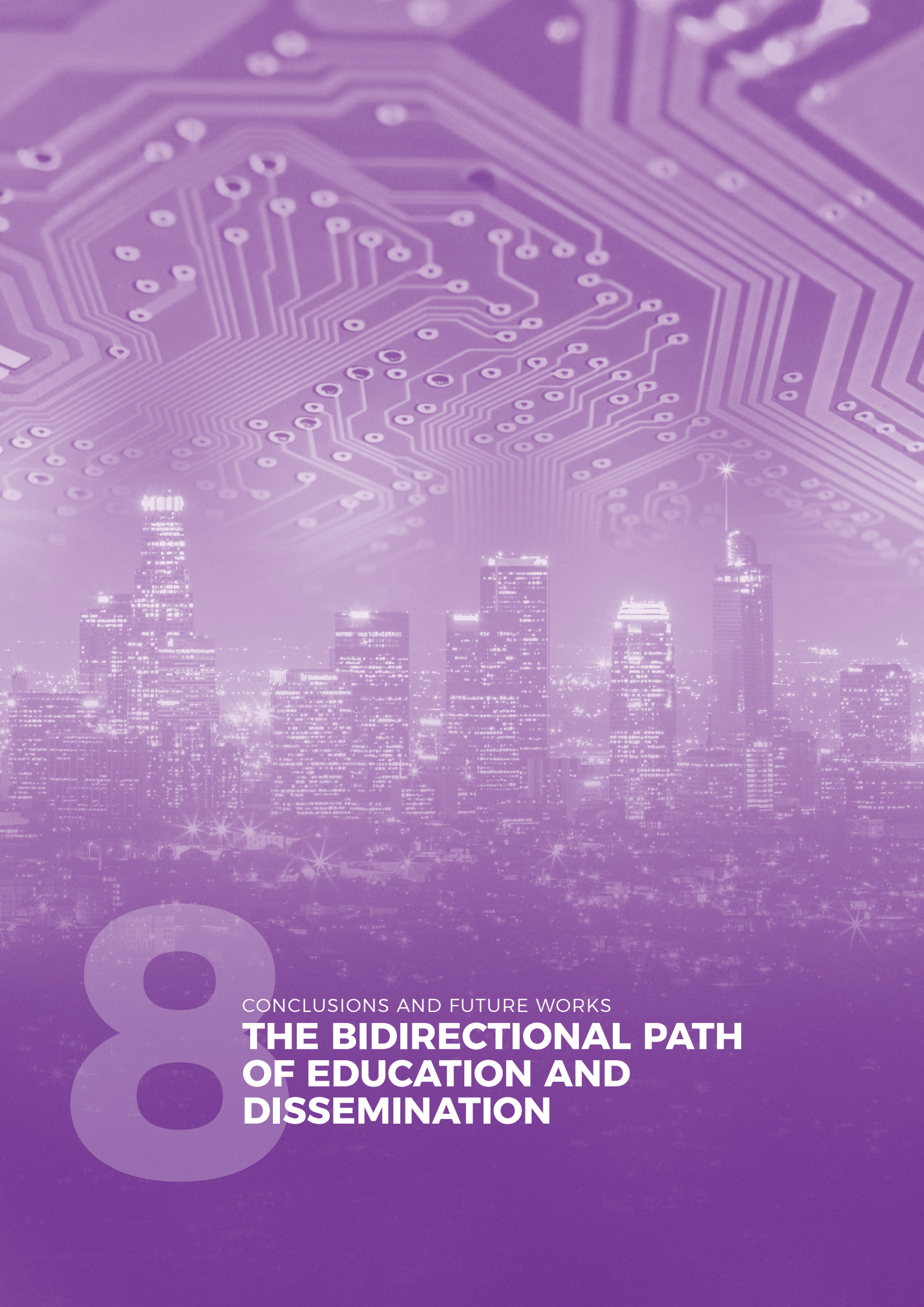


8

CONCLUSIONS AND FUTURE WORKS

THE BIDIRECTIONAL PATH OF EDUCATION AND DISSEMINATION

8. Conclusions and future works: The bidirectional path of education and dissemination

In this concluding chapter, the significant insights from this doctoral thesis are revisited. The implications of these findings and their potential to shape future studies are also explored. Therefore, this chapter is not just an endpoint. It is also the gateway that embodies the reciprocal nature of education and dissemination and shows the research lines that will be developed as future works.

8.1 Conclusions

After an initial presentation of the mechanisms for knowledge communication and the interconnections between them (see the Preface), this doctoral thesis has further explored the common areas between public dissemination and education. This section will encapsulate the significant findings and implications of the research developed.

This research has uncovered a positive perception of dissemination videos as a complementary educational resource, underscoring their potential to

enhance learning experiences. This has led to the proposal of metrics to optimize the educational value of these videos, aligning with the literature and paving the way for more effective didactic content creation. The findings also highlight the need for educators to enhance their digital competence and continuously improve their technological, pedagogical, and content knowledge.

It has been suggested that dissemination videos can successfully support conceptual learning, and the development of soft skills, offering a multifaceted approach to education. This has been tested in ERL scenarios, proving that these videos contribute to academic performance, conceptual learning, students' motivation, and their perception of the quality of education.

Finally, a comparative analysis of regular dissemination videos and those optimized for education yielded valuable insights into their respective performances. The benefits of finding a common ground for disseminators and educators are evidenced through this whole doctoral thesis, and further emphasized by such comparative analysis. In the evolving landscape of ICT-enhanced education, advocating for a collaborative approach between education and dissemination might benefit all. It will foster a dynamic, bidirectional exchange that has the potential to revolutionize the way we learn and share knowledge.

This thesis comes to several conclusions related to these outcomes. Firstly, it has underscored the positive perception of dissemination videos as an educational resource. Secondly, it has identified metrics to optimize the educational value of a dissemination video, thereby enhancing its pedagogical efficacy. Thirdly, it highlights the imperative to develop the digital competence of educators and bolster their technological, pedagogical, and content knowledge. Fourthly, it has demonstrated the benefits of dissemination videos in supporting not only motivation but also conceptual learning and the development of soft skills. Fifthly, it has shown the potential of dissemination videos to mitigate the effects of ERL scenarios, based on the experience with the lockdown due to the COVID-19 pandemic in 2020. Sixthly, it has compared the performance of regular dissemination videos with those optimized for education, revealing significant differences. Lastly, it has explored the potential benefits of finding common ground between disseminators and educators, paving the way for more effective collaboration in the future. These conclusions provide a robust contribution to literature and build the foundations for further research in the field. Each one of them is elaborated in the following subsections.

The positive perception of dissemination videos as a complementary educational resource

This research has shown how a dissemination channel, with no prior efforts to optimize its contents for educational use, can be perceived as an interesting educational tool. Most participants from *Sígueme la Corriente* (96.5%) declare to have a positive perception of the potential of didactic videos to enhance education quality. This aligns with the fact that the channel is being used in parallel for both education and entertainment purposes traditionally related to dissemination.

These findings suggest that public dissemination audiovisual resources might be adequate to serve a dual aim as a dissemination material with value as a complementary resource in formal education. In this context, students prefer videos as a complementary resource to enhance the understanding of lecture topics, and they remain negative or neutral to see videos as a complete substitute for assistance-based education. Considering these findings, optimization strategies can be contemplated for audiovisual dissemination resources, seeking to maximize the metrics defining the adequacy of such videos for educational purposes.

Overall, Sígueme la Corriente users recognize videos as a successful resource to enhance their overall educational experience, which could be reviewed as an adequate complementary tool for distance and face-to-face education.

Metrics to optimize the educational value of a dissemination video

As widely exposed in the subsection 1.2.5, there are specific characteristics optimizing videos as a suitable resource for educational settings. These characteristics can be summarized as:

- **Content Adequacy:** Relevant, truthful content that matches the audience's understanding level.
- **Explanation Adequacy:** Clear, efficient, and engaging explanations that are well-structured and contextualized. Complex topics should be broken down into sections or multiple interconnected videos.
- **Visualization Adequacy:** Concepts should be visually represented using relevant images, animations, and graphical representations of the complex and abstract ideas composing STEM disciplines.

- **Format Adequacy:** High audiovisual quality to minimize distractions. The video should feature a presenter for personalization and balance (providing the benefits of having a presenter and showing footage and resource images/animations). Information should be well-distributed and synchronized between visual and auditory channels.

Considering such guidelines, the development of dissemination resources optimized for education in this doctoral thesis has applied the following features:

- These resources are designed to meet the educational needs of teachers and students. Therefore, they are aligned with the content of STEM degrees. Concept maps have been helpful in this regard to adequately select the topics from the curriculum that could most benefit from video-aided reinforcement.
- They count on a deeper focus and more efficient explanations when compared to dissemination videos, and the communicative voice avoids the distractions that otherwise would aim for entertainment.
- The use of animations and visualizations in educational videos is intensified and precisely tailored to support the learning of complex, abstract concepts.
- The mathematical explanations of explained ideas are explicitly included and clarified as part of educational videos when relevant.
- These educational videos are often part of a more comprehensive series, linking new contents to prior knowledge and creating a structured sequence of videos that increase in complexity.

The need to develop the digital competence of educators, as well as enhancing technological, pedagogical, and content knowledge

As outlined in the section 1.2, the use of videos as supplementary teaching tools in higher education offers numerous advantages. However, it can be difficult for educators to find the time, expertise, and resources to create their videos in a suitable format. Online STEM dissemination videos allow educators to utilize high-quality materials as learning resources. In this regard, YouTube can be an invaluable resource given the vast number of videos available on a wide range of specialized subjects.

Finding and successfully integrating “good-quality” educational videos can be challenging. The primary difficulty for educators is determining the

suitability of these videos based on their content, explanation, visualization, and format. For this purpose, educators must count with suitable digital competences and technological knowledge, as exposed in the subsection 1.1.4.

Moreover, the complementary pedagogical knowledge would also complement the selection of adequate videos with skills to develop a proper instructional design. Such a design would optimize the benefits of the video resource for the learning purposes established on the course. And complementarily, the educators' content knowledge is also determinant when evaluating the accuracy and adequacy of the videos' contents, as well as when deciding which topic is adequate to reinforce.

The benefits of dissemination videos to support conceptual learning and soft skills

The use of dissemination videos in education is usually associated with its value to introduce topics engagingly, as a complementary method to spark curiosity and increase the students' interest in the subject. However, this kind of resource could also contribute to support conceptual learning and the acquisition of soft skills.

This research has highlighted how using dissemination videos in real classroom interventions has increased the understanding and learning of complex concepts in STEM disciplines. They also foster the creation of connections between different courses and topics of the degree, that would otherwise be perceived as individual and unrelated. This is due to the videos' focus on contextualizing the messages and the fact that they are structured as series of videos increasing in complexity.

Moreover, videos such as those designed through this doctoral thesis also provide additional information about STEM disciplines to pre-university students, increasing their interest in these areas and considering such fields for potential higher studies. Furthermore, as they are created by an active professional in the discipline, they are helpful to provide first-hand prospects about the professional application of the degrees and the job stability and promotion. Finally, this practical approach reinforces students' familiarization with specialized jargon and common practices in the discipline.

These videos also have the potential to influence parameters such as academic stress and anxiety, and enhance the students' motivation, which are parameters affecting dropout rates in STEM studies.

The use of dissemination videos to mitigate the effects of ERL scenarios

The videos developed in this doctoral thesis have been found to promote independent study and active learning, with some participants declaring an increase in academic performance and interest in the subject. These videos were particularly helpful in understanding the subjects' concepts, allowing for repeated viewing and self-paced learning. Furthermore, this was also complemented by their integration of these videos with concept discussion and problem resolution in tutored activities during class.

This help in conceptual learning was particularly evident in theory exams, where the proposed videos contributed mitigating the impact of ERL. However, problems exams and laboratory tests were still negatively impacted by ERL. End-semester examinations yielded better results than mid-semester ones, suggesting an inherent improvement in performance over time, potentially due to a regularization of the new teaching and learning methodologies.

While didactic videos can mitigate some of the adverse effects of ERL scenarios by supporting conceptual learning and promoting increased study time and self-paced learning, they were insufficient to fully offset the impact of such a significant shift in learning paradigms. Instead, they served as a cushioning measure. Therefore, the proposed videos have proven to positively impact learning, performance, interest, and motivation.

The comparative performance of regular dissemination videos vs. dissemination videos optimized for education

After a data-driven analysis over six years for *Sígueme la Corriente* STEM YouTube channel, with owners' data, interesting insights have been collected. Over this period, the channel has transitioned from solely disseminating STEM content to a dual-purpose channel focusing on contents optimized for education.

The findings indicate that the channel's shift towards an educational purpose has enhanced its performance. The channel's usage has significantly increased due to the production of content designed to serve as a pedagogical aid. These results have revealed that the educational use of a YouTube channel like this might significantly surpass the usage for entertainment or satisfying curiosity, typically associated with YouTube as a social media platform. Furthermore, it was found that video length plays a crucial role in viewer

engagement, with a significant correlation observed between video length and retention rate. In this regard, the educational content was found to be more sensitive to this factor than the dissemination content.

These findings endorse integrating a focused educational strategy into STEM dissemination YouTube channels. With appropriate content creation criteria that optimize their suitability for pedagogical integration and curricular alignment, this new approach presents an intriguing opportunity.

The potential benefits of finding common ground for disseminators and educators

This doctoral thesis has contemplated incorporating a specific educational focus into already existing STEM dissemination YouTube channels. This could benefit both educators and content creators.

On the one hand, for educators, this could lead to an increase in the availability of high-quality materials that are already optimized for their integration into educational settings. These materials could supplement classroom teaching, provide additional resources for students, or even serve as the basis for active learning methodologies.

On the other hand, for content creators, catering to this educational need could help them reach a new audience segment: educators and students. This could potentially increase their viewership and subscriber base. Moreover, by diversifying the purpose of their channel to include an optimal approach for education along with a dissemination purpose, they could enhance the appeal and usage of their channel. It could make their channel a go-to resource not just for individuals interested in STEM fields, but also for those actively involved in STEM education.

However, public dissemination content creators often lack specific pedagogical strategies to support the creation of their products. This could raise questions about their actual educational appropriateness. If such unintentional educational use is accurately identified, it could act as a catalyst for implementing strategies to optimize the educational value of their contents. These strategies could guide the development plan of future material, ensuring that they are informative or entertaining, and pedagogically sound and effective for learning.

Overall, considering a complementary educational strategy parallel to the focus of public disseminators could be a win-win situation for both educators and content creators. It is a bidirectional path between dissemination and

education that could enhance the educational landscape by providing quality and accessible resources for learning, while also helping content creators expand their reach and impact.

8.2 Future research lines

Building on the findings and insights from this doctoral thesis, three future research lines have been identified: Educational technology for the Didactics of Mathematics, digital competences for educators and students, and connections between public dissemination and education. The following subsections will further describe these future workstreams.

Educational Technology for the Didactics of Mathematics

This doctoral thesis describes how the high presence of abstract concepts in STEM disciplines increases the cognitive demands during their learning process. However, mathematics represents the greatest exponent of abstraction. Therefore, it would be remarkably beneficial to incorporate educational technologies that might reduce the cognitive load during the learning process of mathematical concepts.

Technology-aided learning, such as video learning, could be particularly beneficial. For instance, video learning could provide visual representations of abstract concepts, making them more tangible and understandable. This aligns with the findings of this thesis, which highlighted the potential of integrating multimedia dissemination resources in the classroom, particularly for subjects with a high presence of abstract concepts.

Computational thinking, on the other hand, could help students develop problem-solving skills and logical reasoning that are fundamental in Mathematics. It involves understanding a problem and its constraints, formulating it similarly as a computer would process it, and developing an algorithmic solution. Educational technologies can play a pivotal role in cultivating computational thinking. For instance, programming environments and coding platforms can provide students hands-on experience in algorithmic thinking and problem-solving. They allow students to experiment with different solutions, understand the implications of their decisions, and learn from their mistakes in a controlled environment. Its incorporation together with active

learning methodologies can also facilitate collaborative learning, where students can work together on problems, enhancing their computational thinking skills while developing teamwork and communication skills.

Future research could investigate the most effective ways to integrate these strategies into the classroom, and their impact on conceptual learning, procedural learning, academic performance, and both interest and motivation. This research line has already been started since 2023 under the framework of a *Venia Docendi* agreement with the Area of Didactics of Mathematics of the Department of Mathematics at the *Universidad de Las Palmas de Gran Canaria*.

Digital Competences for Educators and Students

The outcomes of this doctoral thesis have underscored the need for educators to possess an advanced level of digital competences to create, select and integrate adequate audiovisual resources. Future research will focus on strategies for evaluating and improving educators' digital competence. This could also extend to students, exploring how to equip them with the necessary digital skills to utilize these educational technology resources effectively.

On the one hand, for educators, this could involve an appropriate evaluation of their digital competences based on the DigCompEdu framework. With this information, this research line will explore the implications of specific training in using educational technologies, considering TPACK framework, such as how to create and integrate video learning resources into their instructional design.

On the other hand, for students, this could involve developing their skills in using these technologies for learning. This could include technical skills, such as how to access and navigate these resources, and meta-skills, such as how to manage their learning when using these resources effectively.

This research line has already started since 2023 under the framework of the project *UNIDIGITAL DigCompEdu – Formación y Certificación*, with three years of duration between 2022 and 2024. This research involves measuring and analyzing the digital competence of academics in the two public universities of the Canary Islands: *Universidad de Las Palmas de Gran Canaria* and *Universidad de La Laguna*. It will allow the study of how the singular situation of the Canary Islands might be a factor impacting the digital competence of its academics.

Connections between Public Dissemination and Education

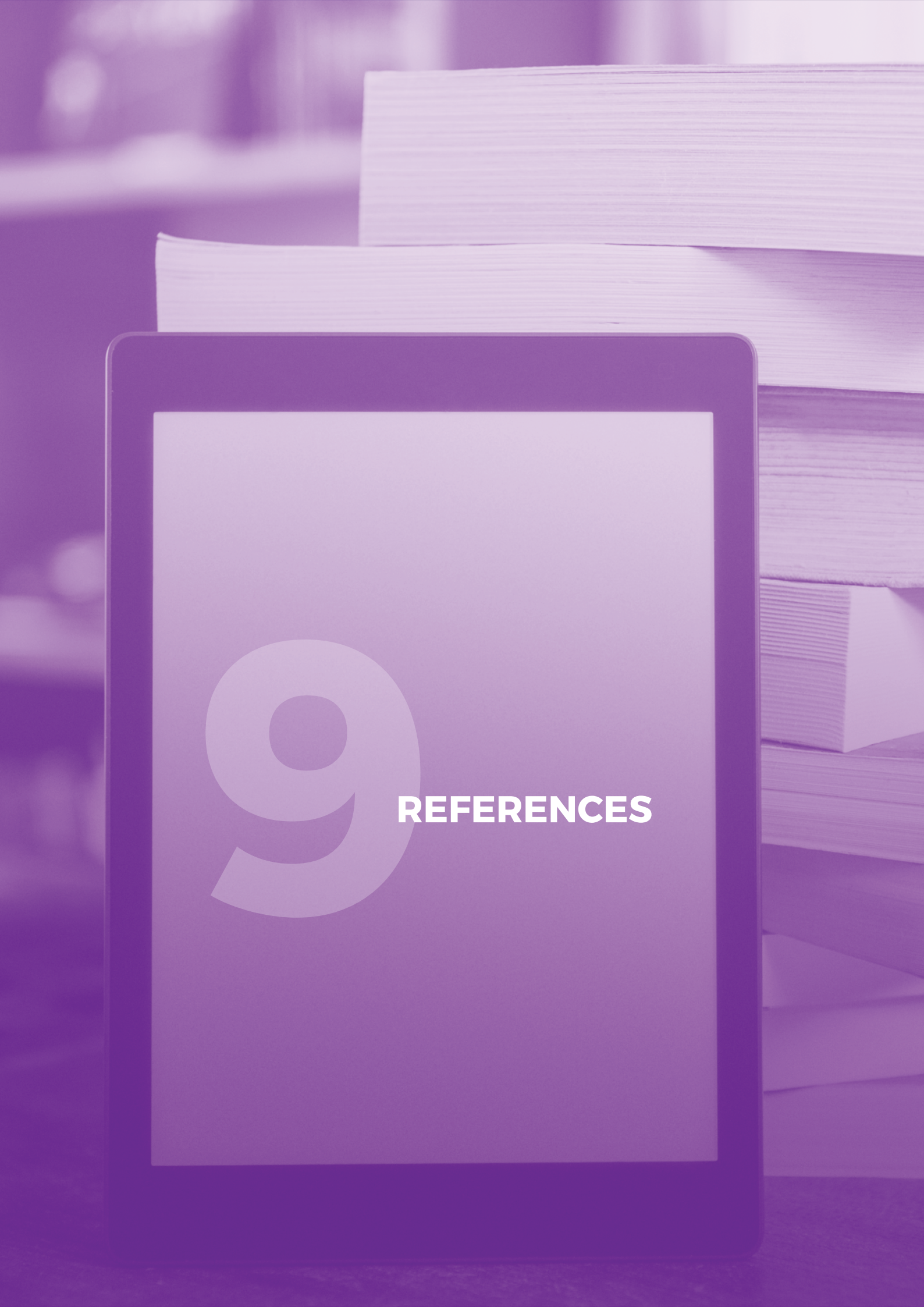
This doctoral thesis has demonstrated the potential of STEM dissemination resources for educational use, aligned with current literature. Future research could explore this connection further, studying how public dissemination resources can be further optimized for educational purposes.

This could involve studying the behavior and interests of users, the impact of content strategy and curricular alignment, and the potential for these resources to serve as a bridge between education and dissemination. More evaluations will be performed in dissemination channels like *Sígueme la Corriente* to extrapolate the findings of this doctoral thesis. And furthermore, this approach will also be expanded to other dissemination formats apart from multimedia resources.

Moreover, platforms created to foster a dual use of multimedia resources for public dissemination and education will be further studied. This is the case of *Amautas*, which is currently targeted as an object of study aligned with the research line followed by this doctoral thesis. This research started in 2023 and involves an initial pre-experimental observational study using the platform's data. It will allow us to evaluate the perception of the platform's users about its content's suitability for educational purposes, considering its dual intention. It will consider the main metrics to evaluate the adequacy of educational videos based on content, format, and communicative style adequacy (see the subsection 1.2.5). Furthermore, this study will be followed by additional studies to explore strategies for aligning *Amautas*' content with official curriculums for various STEM courses in secondary and tertiary education. Guidelines will be established for creating new content that aligns with this curricular approach. This alignment will simplify the integration of resources from a pedagogical perspective, promoting the use of such resources in educational settings.

And finally, the role of multimedia resources in students' active learning will also be explored. Classroom interventions will be developed, proposing students' engagement in creating videos explaining the process resolution of specific STEM problems aligned with the academic curriculum and the syllabus. Afterward, a peer-review methodology will be put in place where students can also review the videos developed by their classmates. Both the video creation and review will be aimed at fostering conceptual learning and procedural learning, as well as setting a regular study-homework routine. This initiative is also expected to improve their participation in class, motivation, critical thinking, and academic performance, and foster their digital competences and presentation skills.

These future research lines not only build on the findings of this thesis but also open new avenues for exploration in the field of STEM education. They highlight the potential of educational technology, particularly video learning and computational thinking, to enhance the teaching and learning of abstract concepts. They also underscore the importance of digital competence for educators and students and the potential of public dissemination channels as educational resources. As such, they represent exciting directions for future research in this field.



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10

APPENDIX

DISSEMINATION OF RESEARCH RESULTS

10. Appendix: Dissemination of research results

The appendix of this doctoral thesis is dedicated to showcasing the extensive dissemination efforts undertaken to share the research findings with a broader audience. It comprises the dissemination articles written by the author, as well as the press coverage that the research has received. This comprehensive compilation serves as a testament to the reach and influence of the research conducted. It also underscores the commitment to fostering open and widespread knowledge sharing.

Dissemination articles

This section of the appendix is presenting the dissemination articles written to publicly share the results of this doctoral thesis.

- **Dissemination Article:** *Conceptos abstractos que se aprenden mejor en vídeo* [Abstract concepts that are best learned on video][41]. **Published in 2022 at:** The Conversation.
- **Dissemination Article:** *Cómo seleccionar vídeos adecuados para uso educativo* [How to select adequate videos for educational use][42]. **Published in 2024 at:** The Conversation.

Moreover, three additional dissemination articles have already been accepted, which will be published in the following sites and magazines:

- **Mapping Ignorance**[43]: This is an online scientific communication site edited in English by the Chair of Scientific Culture of the *Universidad del País*

[41] https://theconversation.com/conceptos-abstractos-que-se-aprenden-mejor-en-video-184078 (Accessed 15/04/2024).
[42] https://theconversation.com/como-seleccionar-videos-adecuados-para-uso-educativo-223132 (Accessed 15/04/2024).
[43] https://mappingignorance.org (Accessed 15/04/2024).

Vasco, under the Project Campus of International Excellence – Euskampus. Their goal is to translate cutting-edge scientific research into an educated lay-person language and, therefore, contribute to map ignorance with new knowledge.

- Cuaderno de Cultura Científica[44]: This is an online scientific communication site also edited in Spanish by the Chair of Scientific Culture of the *Universidad del País Vasco*, under the Project Campus of International Excellence – Euskampus. Its activity aims to publish news about recent research, as well as general dissemination articles, opinion articles, and materials contributing to the construction of a scientific culture.
- Hipótesis Magazine[45]: This magazine is edited by the Scientific Culture and Innovation Unit of *Universidad de La Laguna* (UCC+i - *Cienci@ULL*), in cooperation with the *Consejería de Economía, Conocimiento y Empleo* at the Government of the Canary Islands, through the *Agencia Canaria de Investigación, Innovación y Sociedad de la Información*. It is a dissemination magazine designed to bring closer to society the research developed at the *University of La Laguna*.

[44] https://culturacientifica.com (Accessed 15/04/2024).
[45] https://www.ull.es/portal/cienciaull/revistahipotesis (Accessed 15/04/2024).

Conceptos abstractos que se aprenden mejor en vídeo

Publicado: 7 julio 2022 19:15 CEST

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Las disciplinas de Ciencia, Tecnología, Ingeniería y Matemáticas (comúnmente agrupadas por el acrónimo CTIM, o STEM a partir de sus siglas en inglés *Science Technology, Engineering and Maths*) suelen estar repletas de conceptos abstractos que dificultan su comprensión.

Si pensamos, por ejemplo, en los imanes de nuestra nevera, es medianamente intuitivo comprender que existe una fuerza de atracción que los impulsa a fijarse a la superficie. Pero esta intuición viene de nuestra experiencia acumulada. Lo que no es quizá tan intuitivo es imaginar las líneas de campo magnético que efectivamente modelan y describen este comportamiento físico. Es esta clase de ideas abstractas las que hacen de las disciplinas CTIM unas ramas de conocimiento particularmente desafiantes a la hora de abordar su aprendizaje.

Conceptos abstractos y vídeo

Normalmente, en el aula nos apoyamos de representaciones visuales en la pantalla o la pizarra, y ejemplificaciones que ayuden al estudiantado a dar forma a estos conceptos teóricos y abstractos.

Mediante similitudes y representaciones se facilita el proceso de aprendizaje, en el cual el profesorado únicamente puede ejercer de guía, pero depende del alumnado culminarlo con la comprensión completa de los fenómenos estudiados.

El impacto del confinamiento

Durante el confinamiento a causa de la pandemia vivida en los últimos años, y la consecuente necesidad de trasladar la docencia al formato telemático, se evidenció también un aumento en las dificultades para trasladar de manera efectiva este tipo de conocimientos. La brecha digital y el desigual acceso a la tecnología y su uso implicaron complicaciones adicionales, que se unían a una sensación notable de aislamiento y falta de motivación.

A este respecto, el vídeo como soporte visual presenta un papel más que relevante. Empleado como apoyo a la actividad docente, brinda la capacidad de ayudar a la comprensión de ideas complejas mediante su representación animada. También puede servir para la mejora en la motivación del estudiantado, al ser un formato digital más cercano a su manera de comunicarse y a las tendencias actuales de difusión del conocimiento fuera de las aulas.

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Divulgación científica y YouTube

Claro que no todo el profesorado dispone de recursos, tiempo o conocimientos para desarrollar estos materiales audiovisuales de apoyo a su actividad docente. Sin embargo, las redes sociales, y particularmente YouTube, están llenas de materiales de divulgación científica y técnica que bien podrían ser empleados en el aula con propósitos diversos: desde el repaso de conceptos hasta la puesta en práctica de metodologías como el aula invertida, pasando por el aumento de la motivación de los estudiantes o el fomento del debate y la búsqueda de información.

Nuestra investigación se ha centrado en el uso de recursos de divulgación informal con propósitos educativos y en la evaluación de un canal de YouTube para su integración en las titulaciones de Ingeniería Eléctrica. El canal en cuestión es Sígueme la Corriente, y está especializado en energía y electricidad.

Vídeo resumen del estudio.

El objetivo del estudio se centraba, en primer lugar, en detectar si el canal estaba ya teniendo un uso educativo, aunque no fuese creado con este propósito. Además, se evaluaría la percepción de su audiencia sobre métricas clave para que los vídeos tengan valor pedagógico, así como la opinión de la audiencia sobre los pros y contras de la integración de vídeos en el aula.

Para ello, se elaboró una encuesta que fue facilitada a todos los suscriptores del canal (70 000 usuarios en julio de 2020), de los que se obtuvo una muestra de 912 participantes. Los resultados fueron, sin duda, muy positivos.

Vídeos divulgativos en CTIM

A raíz del estudio, se pudo confirmar que el canal tiene un elevado uso pedagógico aunque este no hubiese sido nunca su objetivo principal (72.7 % de los encuestados hace uso educativo del canal). Sobre todo, este uso se asocia al perfil de estudiantes preuniversitarios, aunque también al de estudiantes universitarios y profesionales del sector eléctrico.

Además, hasta un 82.4 % afirman que la selección de temas que se hace en el canal coincide con sus intereses. Y casi la totalidad de encuestados, 91.6 %, coinciden en que el canal tiene un nivel técnico adecuado para la comprensión de conceptos.

Estos resultados destacados sugieren que el formato y la carga cognitiva de los vídeos divulgativos del canal se perciben como adecuados para su uso educativo. Y este uso complementario nos da la oportunidad de aplicar nuevas estrategias que faciliten su integración en las aulas.

Divulgación y aula invertida

YouTube puede ser una herramienta muy útil para mejorar la enseñanza, complementando la actividad docente. De esta forma, los divulgadores científicos pueden hacer esfuerzos específicos por comenzar a andar ese camino de entrada a las aulas, creando vídeos particularmente enfocados a su uso en docencia. Los vídeos podrían emplearse en clase como apoyo motivacional, y el estudiantado podría utilizarlos para repasar conceptos. Finalmente, el profesorado puede hacer también uso de ellos en estrategias de aula invertida.

Esta línea de investigación se enmarca en los esfuerzos que numerosos investigadores en todo el mundo están realizando hacia la evaluación de la integración de nuevas tecnologías en el aula. Es necesario el desarrollo de nuevos casos prácticos que evalúen las estrategias óptimas para la creación de contenidos y su impacto específico en el aula. Estos han de servir a un propósito dual divulgativo–educativo. No obstante, las perspectivas son muy alentadoras.

CTIM YouTube antisistema vídeo clase invertida enseñanza en línea vídeo educativo

Cómo seleccionar vídeos adecuados para uso educativo

Publicado: 27 febrero 2024 21:54 CET

Lithiumphoto/Shutterstock

Internet está repleto de vídeos divulgativos a los que la comunidad docente recurre constantemente para generar interés sobre temas concretos, o para ilustrar algún concepto de su temario. Y esto sucede aunque dichos vídeos no hayan sido creados con fines educativos. Además, el alumnado accede también a ellos para reforzar su aprendizaje.

Este aspecto se puso de manifiesto al comienzo de nuestra investigación, en la que analizamos el uso educativo de un canal de YouTube que no tenía un propósito pedagógico. Sorprendentemente, de 912 usuarios encuestados un 72.7 % declaró utilizarlo con fines educativos.

Ante esta realidad tan aplastante surge el siguiente planteamiento: si realmente desde el ámbito de la educación se hace un uso tan elevado de los recursos divulgativos, ¿cómo podríamos, desde la creación de contenidos, optimizar la producción para este fin? ¿Cuáles son las características de los vídeos que más se valoran desde la perspectiva pedagógica? ¿Qué tiene que decir a este respecto la investigación actual?

Carga cognitiva esencial

Según define la teoría cognitiva del aprendizaje multimedia, la carga cognitiva esencial es aquella relacionada con el procesamiento de la información para crear representaciones mentales en la memoria de trabajo durante el proceso de aprendizaje. Es la carga cognitiva determinada por la dificultad del contenido a procesar. Por lo tanto, esta carga cognitiva aumenta cuanto más compleja y abstracta sea la disciplina de estudio.

Si pretenden contribuir a lidiar con esta carga cognitiva, los vídeos deben servir de apoyo visual relevante a las explicaciones. Así, se debe priorizar la selección de aquellos vídeos que incluyan animaciones y gráficos para ilustrar los conceptos explicados. De esta manera, se favorece la transmisión de la información a través del doble canal auditivo y visual y se reduce la carga cognitiva.

También es adecuado que los vídeos muestren de forma explícita las expresiones matemáticas relevantes, acompañadas de una ilustración de lo que representan y de una explicación en voz.

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Estilo comunicativo y calidad audiovisual

Por otra parte, la carga cognitiva externa tiene que ver con la forma de presentación de la información y las posibles distracciones asociadas a ella. Dar explicaciones demasiado largas, o usar recursos visuales que distraen y no son relevantes para la explicación, contribuye al aumento de esta carga cognitiva.

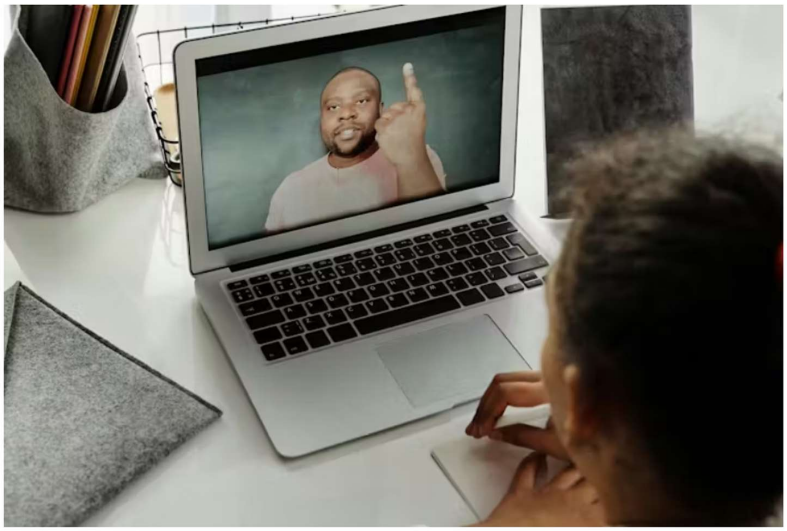


Imagen ilustrativa del uso de un vídeo didáctico. Pexels

La calidad audiovisual es prioritaria para minimizar las distracciones ocasionadas por un audio o imagen defectuosos (con eco, saturado, con mala iluminación, borroso o mal encuadrado). El estilo comunicativo debe ser cercano y claro, gozar de un ritmo de explicación adecuado y mantener el interés de la audiencia.

La importancia de la duración

Es conveniente seleccionar vídeos con explicaciones eficientes y bien dirigidas al tema central. Esto está relacionado parcialmente con la duración de los vídeos, aunque no como parámetro absoluto. Temas más complejos requerirán de más tiempo que otros conceptos más sencillos, pero si comparamos dos vídeos sobre la misma cuestión será una buena práctica seleccionar aquel cuya explicación sea más concisa y ordenada.

En nuestra última investigación analizamos durante 6 años el declive de la tasa de retención en vídeos didácticos conforme aumenta su duración. Comprobamos que, cuanto más largos son los vídeos, menos porcentaje de estos es visualizado por la audiencia. Siempre y cuando el tema a tratar lo permita, es deseable que los vídeos que seleccionemos tengan una duración de entre 5 y 15 minutos.

La audiencia de vídeos educativos es más susceptible a abandonar vídeos largos que la de vídeos divulgativos, probablemente por la búsqueda de una finalidad práctica.

Carga cognitiva relevante: contextualización y conexión de temas

En último lugar, la carga cognitiva relevante se refiere a la vinculación de la nueva información con la existente en la memoria a largo plazo. Este tipo de carga cognitiva aumenta cuando se dificulta la creación de conexiones efectivas entre conceptos de la disciplina.

A este respecto, se deben priorizar aquellos vídeos que vinculen los contenidos explicados con conceptos previos de la misma disciplina, facilitando la contextualización del nuevo conocimiento y fomentando, así, el procesamiento generativo. Además, será un aspecto positivo la existencia de series de vídeos que puedan reproducirse de manera secuencial y escalen en nivel, permitiendo de esta manera un aprendizaje gradual e interconectado.

Sígueme la Corriente

Utilizamos todas estas conclusiones para crear una nueva sección de vídeos en el canal de YouTube analizado, "Sígueme la Corriente". Este contenido, ahora sí, fue creado específicamente para ser utilizado en la educación formal. Tuvimos en cuenta que hubiera un buen apoyo visual de las explicaciones habladas, que la calidad de audio e imagen fuera buena, que la duración del vídeo fuera la óptima, adecuamos el ritmo de las explicaciones y el estilo comunicativo, e hicimos especial hincapié en la conexión de los conceptos explicados con los fundamentos teóricos de la disciplina.

El resultado se plasmó en varias series de vídeos educativos que fueron integrados en el aula con resultados muy positivos. Su uso favoreció el aprendizaje conceptual en áreas complejas y abstractas, y contribuyó al rendimiento académico y la motivación de los alumnos.

Divulgación y educación: un camino bidireccional

Tener en cuenta todos estos factores puede beneficiar tanto a docentes como a creadores de contenido. Por un lado, los creadores de contenido pueden hacer uso de estas indicaciones para dirigir parte de sus vídeos divulgativos a un formato adecuado para su inserción en el aula. Así, mientras mantienen su finalidad divulgativa, conseguirán añadir una nueva dimensión a su canal que favorecerá su uso y popularidad.

Visualización de conceptos relacionados con Educación, y disciplinas de Ciencia, Tecnología, Ingeniería y Matemáticas. Shutterstock

Por otro lado, la consideración de los factores anteriores garantizará la selección del vídeo más adecuado para fines didácticos. Serán vídeos optimizados para reducir la carga cognitiva de las explicaciones. Vídeos que serán, para el profesorado, su mejor aliado en el aula.

metodologías pedagógicas · vídeo educativo · edutubers · recursos docentes

Press coverage

This section of the appendix is presenting the thesis' press cogerage.

- **National newspaper:** *Un estudio científico desestigmatiza YouTube en las aulas* [Scientific study destigmatizes YouTube in the classroom][46]. **Published in 2023 at:** La Razón (online and paper).
- **National newspaper:** *Un exalumno de la UPC triunfa en youtube divulgando ingeniería eléctrica* [A UPC alumnus triumphs on youtube through electrical engineering dissemination][47]. **Published in 2023 at:** La Vanguardia.
- **Regional newspaper:** *El 70% de los estudiantes utiliza YouTube para profundizar y mejorar en los estudios* [70% of students use YouTube to further and improve their studies][48]. **Published in 2023 at:** La Provincia (online and paper).
- **Regional newspaper:** *Un enginyer elèctric a qui seguir el corrent* [An electrical engineer to follow the current][49]. **Published in 2023 at:** Diari de Terrassa (online and paper).
- **Regional newspaper:** *"Sígueme la corriente": el canal de un exalumno de ESEIAAT triunfa en YouTube* ["Sígueme la Corriente": the channel of an ESEIAAT ex-student triumphs on YouTube][50]. **Published in 2023 at:** Món Terrassa.
- **Regional newspaper:** *"El youtuber de l'enginyeria elèctrica té ADN de Terrassa* [The youtuber of electrical engineering has DNA from Terrassa][51]. **Published in 2024 at:** Món Terrassa.
- **Regional TV channel:** *El youtuber Rubén Lijó publica un nou vídeo gravat íntegrament a l'ESEIAAT* ["Youtuber Ruben Lijo publishes a new video recorded entirely at ESEIAAT][52]. **Published in 2024 at:** Terrassa Digital.
- **Institutional Communication:** *La ULPGC lidera un estudio sobre el uso de materiales audiovisuales como recurso pedagógico en las enseñanzas STEM* [ULPGC leads a study on the use of audiovisual materials as a teaching resource in STEM education][53]. **Published in 2022 at:** Universidad de Las Palmas de Gran Canaria.

[46] https://www.larazon.es/ciencia/estudio-cientifico-desestigmatiza-youtube-aulas_20230405642d9aae1036390001b70648.html (Accessed 15/04/2024).
[47] Available in Appendix.
[48] https://www.laprovincia.es/sociedad/2023/03/03/educacion-youtube-estudiantes-tecnologias-84072665.html (Accessed 15/04/2024).
[49] https://www.diarideterrassa.com/terrassa/2023/03/31/un-enginyer-electric-a-qui-seguir-el-corrent (Accessed 15/04/2024).
[50] https://monterrassa.cat/es/economia-es/alumno-eseiaat-videos-youtube-326165 (Accessed 15/04/2024).
[51] https://monterrassa.cat/societat/video-youtuber-enginyeria-electrica-te-adn-de-terrassa-393152 (Accessed 15/04/2024).
[52] https://terrassadigital.cat/el-youtuber-ruben-lijo-publica-un-nou-video-gravat-integrament-a-leseiaat (Accessed 15/04/2024).
[53] https://www.ulpgc.es/noticia/2022/02/04/ulpgc-lidera-estudio-uso-materiales-audiovisuales-como-recurso-pedagogico (Accessed 15/04/2024).

- **Institutional Communication:** *La ULPGC lidera un estudio de integración de vídeos didácticos para mejorar la enseñanza de ingeniería* [ULPGC leads a study on the integration of didactic videos to improve engineering teaching][54]. **Published in 2023 at:** Universidad de Las Palmas de Gran Canaria.
- **Institutional Communication:** *Dos investigadores de la ULPGC ofrecen pautas en The Conversation para escoger vídeos adecuados con fines educativos* [Two ULPGC researchers offer guidelines in The Conversation for choosing appropriate videos for educational purposes][55]. **Published in 2024 at:** Universidad de Las Palmas de Gran Canaria.
- **Institutional Communication:** *ULL y ULPGC estudian el uso de materiales audiovisuales como recurso pedagógico en las enseñanzas STEM* [ULL and ULPGC study the use of audiovisual materials as a pedagogical resource in STEM education][56]. **Published in 2022 at:** Universidad de La Laguna.
- **Institutional Communication:** *Un 'alumni' de la ESEIAAT de la UPC triunfa en YouTube con 'Sígueme la Corriente', un canal divulgativo de Ingeniería Eléctrica* [An 'alumni' of the ESEIAAT of the UPC triumphs on YouTube with 'Sígueme la Corriente', an informative channel on Electrical Engineering][57]. **Published in 2023 at:** Universitat Politècnica de Catalunya.
- **Institutional Communication:** *Un exalumne de l'ESEIAAT de la UPC triomfa a YouTube amb 'Sígueme la corriente', un canal divulgatiu d'enginyeria elèctrica* [A former student of the ESEIAAT of the UPC triumphs on YouTube with 'Sígueme la corriente', an informative channel on electrical engineering][58]. **Published in 2023 at:** Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa ESEIAAT – UPC.
- **Institutional Communication:** *Ruben Lijó, el 'youtuber' més seguit d'enginyeria elèctrica, publica un nou vídeo al canal 'Sígueme la corriente'", gravat íntegrament a l'ESEIAAT de la UPC* [Ruben Lijo, the most followed 'youtuber' in electrical engineering, publishes a new video on the channel 'Follow me the current'", recorded entirely at the ESEIAAT of UPC][59]. **Published in 2024 at:** Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa ESEIAAT – UPC.

[54] https://www.ulpgc.es/noticia/2023/03/30/ulpgc-lidera-estudio-integracion-videos-didacticos-mejorar-ensenanza-ingenieria (Accessed 15/04/2024).
[55] https://www.ulpgc.es/noticia/2024/03/07/dos-investigadores-ulpgc-ofrecen-pautas-conversation-escoger-videos-adecuados (Accessed 15/04/2024).
[56] https://www.ull.es/portal/noticias/2022/ull-ulpgc-estudian-audiovisuales-recurso-pedagogico-stem(Accessed 15/04/2024).
[57] https://www.upc.edu/es/sala-de-prensa/noticias/alumni-eseiaat-upc-triunfa-youtube-canal-sigueme-la-corriente-ingenieria-electrica (Accessed 15/04/2024).
[58] https://eseiaat.upc.edu/ca/noticies/un-exalumne-de-eseiaat-de-la-upc-triomfa-a-youtube-amb-sigueme-la-corriente-un-canal-divulgatiu-enginyeria-electrica (Accessed 15/04/2024).
[59] https://eseiaat.upc.edu/ca/noticies/ruben-lijo-youtuber-mes-seguit-enginyeria-electrica-publica-un-nou-video-al-canal-sigueme-la-corriente-gravat-integrament-a-eseiaat-upc (Accessed 15/04/2024).

El portal podría ofrecer un contenido pedagógico valioso para la formación académica con evidencias científicas que lo avalan

Un estudio científico desestigmatiza **YouTube** en las aulas

Ignacio Crespo. MADRID

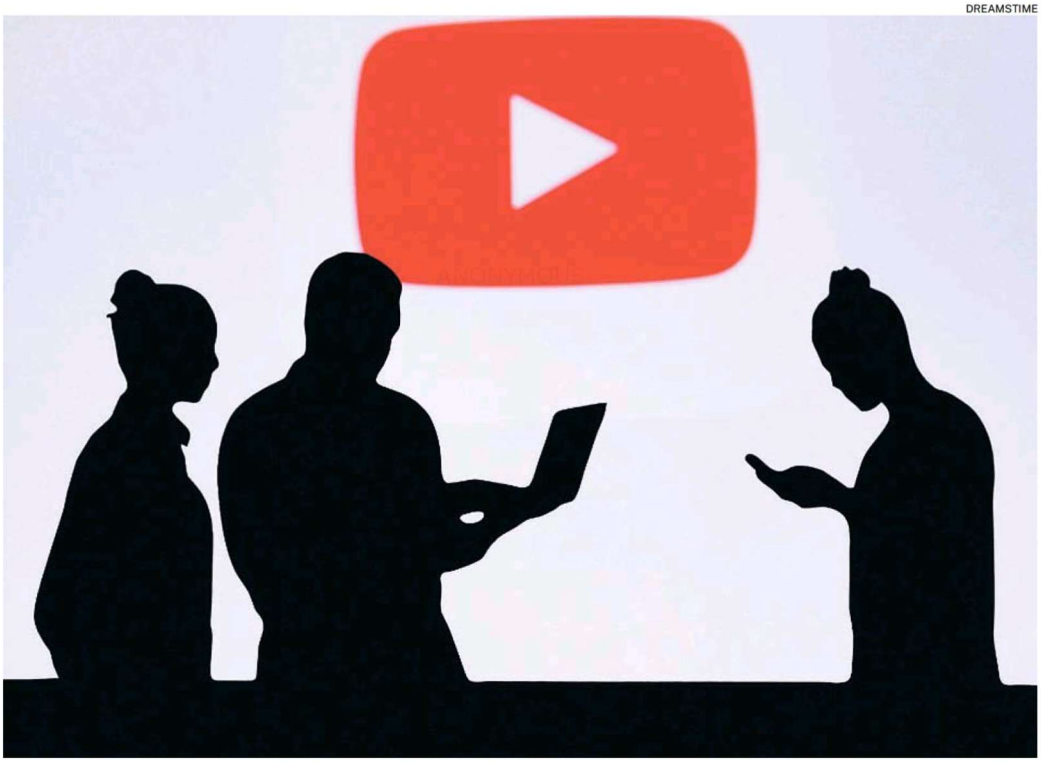
A los seres humanos nos encanta tocar de oído. Es mucho más sencillo trabajar sobre la marcha, cargados de intuición y buenas intenciones. Porque, la alternativa implicaría pararse cada pocos pasos a analizar las evidencias. ¿Tiene sentido lo que estamos haciendo? ¿Cuál es su impacto real? ¿Es posible que estemos perdiendo el tiempo a pesar de nuestro esfuerzo? Y, seamos realistas, nos encanta pensar que lo que hacemos tiene un gran valor social. Nos autoconvencemos con verdaderas piruetas mentales para justificar que las horas dedicadas a nuestro trabajo no son en vano y que con ello estamos haciendo algo importante. El caso de la educación es paradigmático. ¿Cómo va a ser mala cualquier metodología en la que se ofrezca información comprensible a los alumnos? O, mejor dicho, más que «mala», «ineficiente». Asumimos que todo aporta y que nunca está de más un granito de arena, pero ya que los recursos son limitados, tal vez debamos controlarnos y evitar hacer afirmaciones apresuradas. Hay metodologías científicas que pueden aportar rigor a estas cuestiones, analizando hasta qué punto cumplen lo que dicen ofrecer. Eso es, precisamente, lo que están intentando investigadores como el ingeniero eléctrico y doctorando en educación en la Universidad de la Laguna, Rubén Lijó, poniendo bajo el microscopio si, efectivamente, YouTube y los vídeos divulgativos pueden ser un buen complemento para el mundo académico.

Un propósito claro

Se ha hablado mucho y muy mal sobre el uso de nuevas tecnologías en las aulas. En parte con razón, porque muchas veces no hay nadie al volante cuando se decide comprar un cargamento de «tablets» para un colegio. Subirse al carro de la enseñanza 2.0 va primero y buscarle un uso al material acaba quedando relegado a un segundo plano que, por lo tanto, posiblemente tenga bastantes deficiencias. Ahora bien, no por ello debemos condenar toda comunión entre lo digital y las aulas. Y, más o menos, eso es lo que pretendía aclarar Rubén Lijo. En sus propias palabras: «el objetivo inicial era poder dotar a la comunidad docente de recursos contrastados para que puedan mejorar su trabajo, explorando el uso dual de los vídeos didácticos para, por un lado, contribuir a la divulgación y, por otro, a la educación». ¿Este tipo de vídeos pueden tener un uso exitoso en ambas áreas? Esa era la pregunta central, aclara Lijó. «El principal problema en el aula con la integración de contenido audiovisual puede ser la falta de tiempo y recursos por parte del docente para elaborar sus propios vídeos, alineados con su docencia, pero si tenemos en cuenta que hay un abanico muy amplio de vídeos de contenido educativo en YouTube y otras redes sociales, en distintos temas de las ciencias, la tecnología, la matemática y la ingeniería, podemos considerar que, si se demuestra su valor pedagógico, ya no habrá escusas». Así pues, Rubén Lijó ha desarrollado en su canal de YouTube una serie de nueve vídeos pedagógicos dedicados a la asignatura de «Máquinas Eléctricas I» de la Escuela Superior de Ingenierías Industrial, Aeroespacial y Audiovisual de Terrasa de la Universidad Politècnica de Catalunya.

La falta de tiempo o de recursos son problemas a los que se enfrentan los docentes

DREAMSTIME



Educando con YouTube

Muchas iniciativas habrían terminado aquí, pero Rubén Lijó, sus directores de tesis en la Universidad de las Palmas de Gran Canaria y el profesor Ricard Horta, sabían que era importante medir el impacto. Analizaron las calificaciones obtenidas por el alumnado y los resultados fueron muy positivos, demostrando que estos vídeos podían tener un efecto interesante en el mundo académico. Para ello, los investigadores siguieron a 157 alumnos durante 3 cursos. Pero las evidencias no acaban aquí. Como parte de su tesis, Rubén Lijó ha recogido mucha más información acerca de los usuarios de su canal, que cuenta con más de 150.000 seguidores y acumula en torno a las 4,5 millones de visualizaciones.

En una encuesta en la que participaron 912 suscriptores del canal, sus respuestas indicaron que existe un amplio uso educativo de este y una percepción general de que su contenido y formato son adecuados para tal propósito. «Es decir –añade Lijó– serían un recurso pedagógico muy amplio y variado, al cual todos los docentes tienen acceso y pueden hacer uso de él en el aula para mejorar la experiencia docente y el aprendizaje de los alumnos». Porque podemos seguir nutriendo las redes con contenido educativo de una forma casi compulsiva, pero sin estudios que avalen su impacto, puede que todo ese esfuerzo sea en vano. Así lo resume Lijó: «Esa es la motivación de fondo de esta investigación: tomar esos recursos que ya están disponibles, hacer una evaluación de las características que definirían si son adecuados o no y una vez verificado, integrarlos en el aula.

El próximo reto estará en que los docentes tengan unas adecuadas competencias digitales para que puedan integrar adecuadamente los recursos audiovisuales que están disponibles».

La integración de las nuevas tecnologías en el aula plantea debates sobre su idoneidad

Un estudio científico desestigmatiza YouTube en las aulas

YouTube podría ofrecer un contenido pedagógico valioso para la formación académica y ahora hay más evidencias científicas que lo avalan.

▲**Rubén Lijó observando el infinito entre un campo de maquetas de aerogeneradores** Alby Martín / Alby Martín

IGNACIO CRESPO @SdeStendhal

Madrid Creada: 05.04.2023 17:58
Última actualización: 05.04.2023 17:58

A los seres humanos nos encanta tocar de oído. Es mucho más sencillo trabajar sobre la marcha, cargados de intuición y buenas intenciones. **Porque, la alternativa implicaría pararse cada pocos pasos a analizar las evidencias.** ¿Tiene sentido lo que estamos **haciendo**? ¿Cuál es su impacto real? ¿Es posible que estemos perdiendo el tiempo a pesar de nuestro esfuerzo? Y seamos realistas, nos encanta pensar que lo que hacemos tienen un gran valor social. **Nos autoconvencemos con verdaderas piruetas mentales para justificar que las horas dedicadas a nuestro trabajo no son en vano y que con ello estamos haciendo algo importante. El caso de la educación es paradigmático.**

¿Cómo va a ser mala cualquier **metodología** en la que se ofrezca información comprensible a los alumnos? O, mejor dicho, más que "mala", "ineficiente**". Asumimos que todo aporta y que nunca está de más un granito de arena, pero ya que los recursos son limitados, tal vez debamos controlarnos y evitar hacer afirmaciones apresuradas.** Hay metodologías científicas que pueden aportar rigor a estas cuestiones, analizando hasta qué punto cumplen lo que dicen ofrecer. **Eso es, precisamente, lo que están intentando investigadores como el ingeniero eléctrico y doctorando en educación en la Universidad de la Laguna, Rubén Lijó, poniendo bajo el microscopio si, efectivamente, YouTube y los vídeos divulgativos pueden ser un buen complemento para el mundo académico.**

Un propósito claro

Se ha hablado mucho y muy mal sobre el uso de **nuevas tecnologías** en las aulas. En parte con razón porque muchas veces no hay nadie al volante cuando se decide comprar un cargamento de tablets para un colegio**. Subirse al carro de la enseñanza 2.0 va primero y buscarle un uso al material acaba quedando relegado a un segundo plano que, por lo tanto, posiblemente tenga bastantes deficiencias. Ahora bien, no por ello debemos condenar toda comunión entre lo digital y las aulas.** Y, más o menos, eso es lo que pretendía aclarar Rubén Lijo. En sus propias palabras *"El objetivo inicial era poder dotar a la comunidad docente de recursos contrastados para que puedan mejorar su docencia, explorando el uso dual de los vídeos didácticos para, por un lado, contribuir a la divulgación y, por otro, a la educación".*

¿Este tipo de vídeos pueden tener un uso exitoso en ambas áreas? Esa era la pregunta central, aclara Lijó. *"El principal problema en el aula con la integración de contenido audiovisual puede ser la falta de tiempo y recursos por parte del docente para elaborar sus propios vídeos, alineados con su docencia, pero si tenemos en cuenta que hay un abanico muy amplio de vídeos de contenido educativo en YouTube y otras redes sociales, en distintos temas de las ciencias, la tecnología, la matemática y la ingeniería, podemos considerar que si se demuestra su valor pedagógico ya no habrá escusas".*Así pues, Rubén Lijó ha desarrollado en su canal de YouTube (*Sígueme la Corriente*) una serie de 9 vídeos pedagógicos dedicados a la asignatura de "Máquinas Eléctricas I" de la *Escuela Superior de Ingenierías Industrial, Aeroespacial y Audiovisual de Terrasa de la Universidad Politècnica de Catalunya.*

Educando con YouTube

Muchas iniciativas habrían terminado aquí, pero Rubén Lijó, sus directores de tesis en la Universidad de las Palmas de Gran Canaria (Eduardo Quevedo, José Juan Castro) y el profesor Ricard Horta, sabían que era importante medir el impacto. Así pues, analizaron las calificaciones obtenidas por el alumnado y la motivación de estos. Los resultados fueron muy **positivos**, demostrando que estos vídeos podían tener un efecto interesante en el mundo académico. Para ello, los investigadores siguieron a 157 alumnos durante 3 cursos.

Pero las evidencias no acaban aquí, como parte de su tesis, Rubén Lijó ha recogido mucha más información acerca de los usuarios de su canal, que cuenta con más de 150.000 seguidores y acumula en torno a las 4,5 millones de visualizaciones. **En una encuesta en la que participaron 912 suscriptores del canal, sus respuestas indicaron que existe un amplio uso educativo de este y una percepción general de que su contenido y formato son adecuados para tal propósito.** *"Es decir [...]"*, añade Lijó, *"[...] serían un recurso pedagógico muy amplio y variado, al cual todos los docentes tienen acceso y pueden hacer uso de él en el aula para mejorar la experiencia docente, el aprendizaje de los alumnos, la motivación y el interés por estas asignaturas y ramas de conocimiento".*

Porque podemos seguir nutriendo las redes con contenido educativo de una forma casi compulsiva, pero sin estudios que avalen su impacto, puede que todo ese esfuerzo sea en vano. Así lo resume Lijó: *"Esa es la motivación de fondo de esta investigación: tomar esos recursos que ya están disponibles, hacer una evaluación de las características que definirían si son adecuados o no en estos contextos pedagógicos en términos de contenido, de formato audiovisual, de presentación, etc. Y, una vez verificado, integrarlos efectivamente en el aula. Ahora que hemos demostrado la validez de este recurso, el próximo reto estará en que los docentes tengan unas adecuadas competencias digitales para que puedan seleccionar e integrar adecuadamente los recursos audiovisuales que están disponibles".*

QUE NO TE LA CUELEN:

- Generalizar los resultados de un estudio siempre es conflictivo, porque normalmente estudiamos una situación concreta, con sus contingencias y peculiaridades. No obstante, los estudios, cuando están bien diseñados, suelen estar preparados para reducir estas particularidades y ser tan generalizables como sea rigurosamente posible. En este caso, como con cualquier otro estudio, podemos encontrar ciertas limitaciones, pero es un paso en firme dentro de las líneas de investigación relacionadas con la docencia y la divulgación.

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ARCHIVADO EN:

Tecnología / Ciencia / Internet

UNIVERSIDAD YOUTUBE

Un exalumno de la UPC triunfa en youtube divulgando ingeniería eléctrica

• Barcelona, 30 mar (EFE).- El exalumno de la Escuela Superior de Ingenierías Industrial, Aeroespacial y Audiovisual de Terrassa (ESEIAAT) de la Universidad Politécnica de Cataluña (UPC) Rubén Lijó está arrasando en YouTube con su canal divulgativo de Ingeniería Eléctrica llamado 'Sígueme la Corriente'.

AGENCIAS

30/03/2023 16:55

Barcelona, 30 mar (EFE).- El exalumno de la Escuela Superior de Ingenierías Industrial, Aeroespacial y Audiovisual de Terrassa (ESEIAAT) de la Universidad Politécnica de Cataluña (UPC) Rubén Lijó está arrasando en YouTube con su canal divulgativo de Ingeniería Eléctrica llamado 'Sígueme la Corriente'.

El exalumno, que es consultor en la empresa Hitachi y estudiante de doctorado en la Universidad de la Laguna "ha logrado hacer de la ingeniería eléctrica un tema de máximo interés, con 150.000 suscriptores y 4,5 millones de visualizaciones de sus vídeos", ha informado la UPC.

Rubén Lijó, junto con los tutores de su tesis doctoral, Eduardo Quevedo, José Juan Castro (ambos profesores de la Universidad de Las Palmas) y con la colaboración de Ricard Horta (profesor del ESEIAAT de la UPC), han publicado un artículo en el que desgranan la utilidad del canal de youtube en la asignatura Máquinas Eléctricas que Ricard Horta impartió durante el período de pandemia.

Ricard Horta ha explicado que habían detectado "la necesidad de reforzar algunos conceptos como el electromagnetismo, o los circuitos trifásicos, que son cruciales para una tercera parte de las asignaturas del grado de Ingeniería Eléctrica" y que el canal 'Sígueme la Corriente' "contiene nueve vídeos didácticos especialmente diseñados para estos dos conceptos".

Por ello, durante la pandemia, los estudiantes utilizaron el canal de Youtube para sus aprendizajes y cuya utilidad han valorado los investigadores a partir de un experimento realizado sobre 157 alumnos de entre 18 y 20 años.

Los estudiantes respondieron a un cuestionario de 32 preguntas y compararon las respuestas obtenidas por dos grupos experimentales y por el grupo de control y también evaluaron con profundidad la afectación de los vídeos sobre la motivación y el compromiso de los estudiantes a lo largo del curso.

Los autores ha concluido que los "resultados evidencian que integrar vídeos didácticos en el aula es muy positivo sobre todo en lo que se refiere al aprendizaje conceptual y al rendimiento académico" y que "el impacto sobre la motivación de los estudiantes ante la asignatura es demostrable y muy satisfactorio".

Según Ricard Horta, "el enfoque práctico de los vídeos y el hecho de que sean desarrollados por un profesional activo del sector son factores que contribuyen a hacer que el alumnado adquiera una perspectiva práctica de la titulación, descubriendo de primera mano las aplicaciones profesionales de sus competencias en la industria".

La investigación, publicada por IEEE Acces, es fruto de la colaboración entre la Universidad de Las Palmas de Gran Canaria, la Universidad de La Laguna y la UPC y se enmarca en el desarrollo de la tesis doctoral del autor principal, Rubén Lijó, titulada "Implicaciones del uso de materiales audiovisuales de divulgación científica como recurso pedagógico en disciplinas STEM". EFE

Ciencia

El 70% del alumnado utiliza YouTube para ahondar y mejorar en los estudios

La plataforma de vídeos se consolida como el nuevo «profesor de refuerzo» entre los jóvenes

María Jesús Hernández
LAS PALMAS DE GRAN CANARIA

Las tradicionales clases de refuerzo no son ajenas a los cambios tecnológicos en el ámbito de la docencia y la formación. Así, la plataforma YouTube se está convirtiendo en el nuevo «profesor particular» al ser el medio más utilizado por las nuevas generaciones para resolver dudas, profundizar en materias y, en general, para adquirir nuevos conocimientos. Así lo afirma un estudio publicado en la plataforma de divulgación científica *The Conversation*, por parte del profesor Carlos González Morcillo de la Universidad Castilla- La Mancha, donde señala que «el 70% de los *millennials* utilizan habitualmente YouTube para aprender o profundizar en sus intereses formativos».

El artículo señala que las nuevas generaciones prefieren aprender mediante un vídeo de YouTube que leyendo un libro. Tanto es así, que el 67% afirma que pueden encontrar en esta plataforma un vídeo de cualquier cosa que quieran aprender.

Con el móvil como principal herramienta de consulta, la principal característica que valoran los estudiantes respecto al uso de la tecnología es la movilidad. «Poder estudiar en cualquier lugar y en cualquier momento». El profesor González destaca que, respecto al uso de tecnología en el ámbito educativo, se valora más la mejora en la calidad de los contenidos, frente a la comunicación con profesores o compañeros de clase o el posible ahorro de tiempo de estudio. «El 94% de los estudiantes aseguran que el uso de la tecnología les ha facilitado el aprendizaje de nuevos conceptos» y prueba de ello es que la plataforma líder de consumo de contenidos digitales es YouTube, «con un 87% de estudiantes que lo utilizan frecuentemente».

Nivel de eficacia

Teniendo en cuenta que la educativa es la segunda categoría de vídeo más consumida en internet -sólo por debajo de contenidos de humor y comedia-, la cuestión está en determinar el nivel de eficacia del aprendizaje en las plataformas *online*. Y en este sentido, Carlos González recuerda que los sentidos «evolucionaron para trabajar de forma conjunta, con relación entre ellos». Cita como ejemplo, el efecto McGurk donde la visión influye sobre el oído: «no percibimos de un modo aislado, sino que el cerebro integra la información multisensorial», lo cual tiene una implicación directa en que «aprendemos mejor» si se estimulan varios sentidos a la vez. «Estos resultados no son nuevos. Los experimentos iniciales de Mayer demostraron que el aprendizaje multisensorial en resolución de problemas (texto narrado y animaciones) mejora los resultados el doble con respecto del equivalente unisensorial con texto escrito e imágenes».

> El 94% de los jóvenes asegura que el uso de la tecnología les facilita el aprendizaje

> Investigadores aconsejan el empleo de los vídeos en clase, como apoyo motivacional

En el ámbito docente, el investigador señala que el estándar de impartición de contenidos lo están fijando los mejores profesores del mundo publicando sus clases en la red. «El alumno puede elegir que le explique el contenido su docente favorito». Como ejemplo, destaca fenómenos como el de David Calle, fundador de la web educativa Unicoos y finalista del Global Teacher Prize 2017, cuyo canal de YouTube cuenta con más de 700 vídeos de Matemáticas, Física y Química y tiene 1,5 millones de suscriptores.

También cita a la Academia Khan, fundada en el año 2006 y cuyo saldo supera los 4.000 vídeos que han sido vistos más de 1.500 millones de veces. Este proyecto es un referente de enseñanza mundial en educación primaria y secundaria basada en vídeos instructivos. La iniciativa, que obtuvo el Premio Princesa de Asturias de Cooperación Internacional en 2019, nació con el objetivo de «proporcionar una educación gratuita de nivel mundial para cualquier persona, en cualquier lugar».

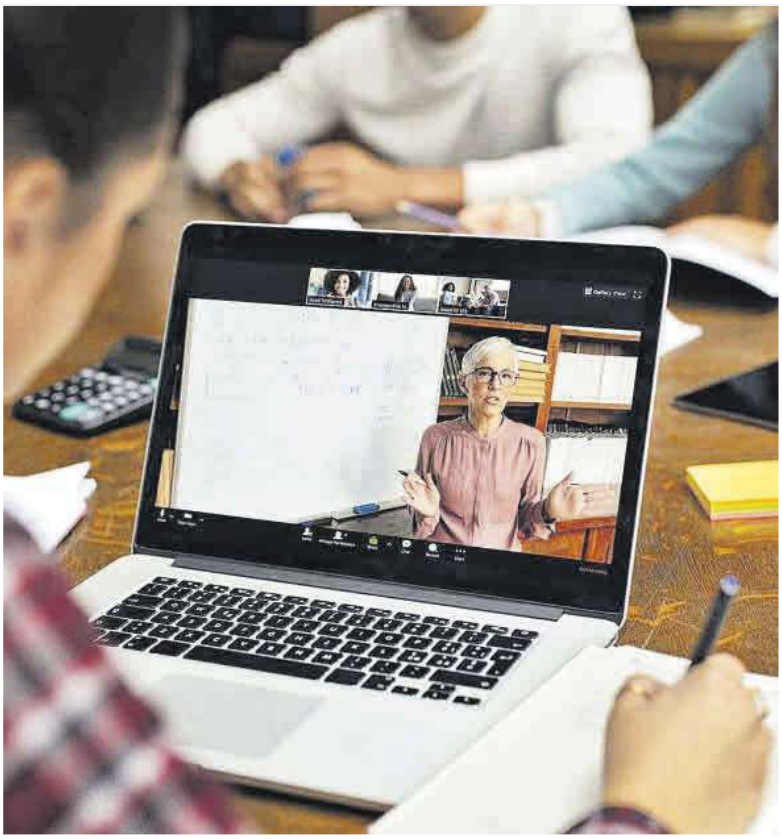
Los profesores de la Universidad de Las Palmas de Gran Canaria (ULPGC), Eduardo Quevedo -Área de Estadística e Investigación Operativa del Departamento de Matemáticas- y José Juan Castro -área de Psicología-, junto con Rubén Lijó Sánchez -estudiante del Programa de Doctorado en Educación de la Universidad de La Laguna-, y Ricard Horta -profesor de Ingeniería Eléctrica en UPC-, analizaron, también en un artículo publicado en *The Conversation*, la importancia de los vídeos en el aprendizaje de los conceptos abstractos, fundamentales en las denominadas disciplinas STEM -Ciencia, Tecnología, Ingeniería y Matemáticas-.

En este trabajo, se centraron en el estudio del uso de recursos de divulgación informal con propósitos educativos y en la evaluación de un canal de YouTube -Sígueme la Corriente-, para su integración en las titulaciones de Ingeniería Eléctrica. El primer objetivo fue detectar si el canal estaba ya teniendo un uso educativo, aunque no fuese creado con dicho propósito; y también se evaluó la percepción de su audiencia sobre métricas clave para que los vídeos tengan valor pedagógico, así como la opinión de los usuarios sobre los pros y contras de la integración de vídeos en el aula. Para ello, se elaboró una encuesta que fue facilitada a los suscriptores del canal (70.000 usuarios en julio de 2020), de los que se obtuvo una muestra de 912 participantes.

Las principales conclusiones del estudio fueron, por un lado, que YouTube puede ser una herramienta muy útil para mejorar la enseñanza, complementando la actividad docente. «Los divulgadores científicos pueden hacer esfuerzos específicos por comenzar a andar ese camino de entrada a las aulas, creando vídeos particularmente enfocados a su uso en docencia». Y por otro, confirmaron la importancia del empleo de los vídeos en clase como apoyo motivacional, de forma que el estudiantado podría utilizarlos para repasar conceptos; al tiempo que proporciona al profesorado introducirse en nuevas estrategias como la del aula invertida.

Carlos González, por su parte, define la clase invertida, como un nuevo modelo docente donde el contenido de la lección se consume en casa y la actividad en clase se dedica a aquello que el alumno no puede hacer de forma autónoma en casa. «Es lo contrario al método habitual de tomar apuntes. Así, la parte más autónoma del aprendizaje se realiza en casa -ver vídeos docentes o leer contenidos en texto escrito-, y en clase la más activa -resolución de ejercicios, problemas o debates entre alumnos-».

En los dos estudios, se posiciona el formato vídeo como un elemento natural de transmisión de información «altamente eficaz» en el ámbito educativo.



Alumno siguiendo una clase por YouToube. | LP/DLP

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LA PROVINCIA
DIARIO DE LAS PALMAS

Educación

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Alumno siguiendo una clase por YouTube. / LP/DLP

María Jesús Hernández
Las Palmas de Gran Canaria 03 MAR 2023 17:28

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> **Investigadores aconsejan el empleo de los vídeos en clase, como apoyo motivacional para el alumnado y elemento innovador para el docente**

Las principales conclusiones del estudio fueron, por un lado, que YouTube puede ser una herramienta muy útil para mejorar la enseñanza, complementando la actividad docente. «Los divulgadores científicos pueden hacer esfuerzos específicos por comenzar a andar ese camino de entrada a las aulas, creando vídeos particularmente enfocados a su uso en docencia». Y por otro, confirmaron la importancia del empleo de los vídeos en clase como apoyo motivacional, de forma que el estudiantado podría utilizarlos para repasar conceptos; al tiempo que proporciona al profesorado introducirse en nuevas estrategias como la del aula invertida.

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#divulgació #enginyeriaelèctrica

Sergi Estapé / @SergiEstape

Un enginyer elèctric a qui seguir el corrent

UNIVERSITAT Rubén Lijó, un exalumne de l'Eseiaat, ha aconseguit 150.000 subscriptors i 4,5 milions de visualitzacions amb vídeos a Youtube sobre l'enginyeria elèctrica

"Sígueme la corriente" compta amb 150.000 subscriptors i 4,5 milions de visualitzacions. No és un canal de Youtube que tracti temes futbolístics ni musicals ni tan sols d'humor. És un canal que difon una temàtica tan concreta com l'Enginyeria Elèctrica i el seu autor, el canari Rubén Lijó, és un exalumne de l'Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa (Eseiaat) de la Universitat Politècnica de Catalunya-BarcelonaTech (UPC).

Un article publicat a la revista científica a "IEEE Acces" revela que els vídeos divulgatius basats en la formació universitària de l'Enginyeria Elèctrica. I com a exemple, se cita aquest canal de Youtube. A més de Lijó, a l'article han participat els dos tutors de la seva tesi doctoral, Eduardo Quevedo, José Juan Castro, professors de la Universitat de Las Palmas de Gran Canaria, i Ricard Horta, professor de l'Eseiaat de la UPC.

"Vaig començar a fer divulgació científica i tècnica, més generalista, amb 17 anys, quan feia primer de carrera", manifesta Lijó i quan va acabar els estudis d'enginyeria elèctrica, va sorgir la creació d'aquest canal, per tractar aquestes temàtiques.

Admet que l'èxit del projecte ha estat una nota força positiva. "No ho vaig fer a la babalà. Primer vaig intentar captar l'atenció del públic en general, amb conceptes científics generals i que no fossin tan específics i, a poc a poc, vaig passar cap a una sensibilitat particular amb tots els temes d'energia i sostenibilitat", assegura.

Rubén Lijó és consultor a l'empresa Hitachi i està estudiant el doctorat a la Universidad de la Laguna / ALBY MARTÍN

Tres eixos

La divulgació en el seu canal de Youtube es fonamenta en tres eixos cabdals pel que fa a continguts. "El primer són vídeos que puguin apellar a la curiositat en general, com si té sentit allò que veiem a les pellícules de 'Matrix', altres estan vinculats a l'actualitat i a la utilitat, per exemple com interpretar la factura elèctrica o per quin motiu apuja el preu de la llum, i un tercer que és el suport als estudiants d'enginyeria, que és on s'emmarca la línia d'investigació que estem investigant", diu Lijó

Recorda que ara "estic acabant el meu doctorat amb aquesta investigació, l'ús que pot tenir una canal de Youtube com aquest i poder avaluar el valor educatiu d'aquests vídeos i si realment suposen una millor en la seva experiència a les aules".

L'estudi s'ha realitzat amb una mostra de 157 estudiants entre 18 i 20 anys, Lijó comenta que "realment estàs important totes les característiques de Youtube, que és el que els enganxa i consumeixen, i ho estàs aprofitant per fer una classe conceptual dinàmica" que pot actuar com a complement i que "el docent pugui aprofitar l'atenció de l'alumne captada" aprofundint en els temes que es veuen en els vídeos.

157

estudiants entre els 18 i 20 anys han participat en una investigació que s'ha publicat a una revista

#educació #curs

Redacció / @diarideterrassa

Una aula d'un centre educatiu de Terrassa / NEBRIDI ARÓZTEGUI

El pròxim curs escolar començarà el dimecres 6 de setembre

El curs escolar 2023-24 començarà el dimecres 6 de setembre en les etapes d'infantil, primària i ESO i el dimarts 12 per a la Formació Professional i el batxillerat, mentre que la resta d'ensenyaments començaran el dilluns 18 de setembre.

Així ho va anunciar ahir el Departament d'Educació de la Generalitat de Catalunya, que ha fixat "un criteri estable" pel que fa als cursos vinents perquè comencin el quart dia laborable de setembre per a l'educació bàsica, i el primer dia laborable després de la Diada per a la postobligatòria.

El conseller Josep Gonzàlez-Cambray va assegurar ahir que es tracta del "camí del mig" entre els interessos dels sindicats i les famílies. El titular d'Educació va assenyalar que la concreció del calendari escolar ha estat "fruit d'un procés de diàleg obert" amb representants de tota la comunitat educativa, assegurant que l'avaluació de l'avançament d'aquest curs s'ha fet a partir d'un debat amb el Consell Escolar i un procés de treball amb la Junta Central de Direccions. El conseller també va defensar que començar la primera setmana de setembre és una bona mesura per a l'alumnat, especialment per al més vulnerable, "ja que redueix la desconnexió a l'estiu i garanteix la igualtat d'oportunitats".

Cambray diu que ha agafat "el camí del mig" entre els interessos dels sindicats i de les famílies

Tardes de setembre lectives

D'altra banda, "per millorar la qualitat de l'educació i de la tasca docent" i a diferència del curs 2022-23, les tardes del mes de setembre seran lectives i no hi haurà compensacions extraordinàries pel que fa als dies, ja que n'hi haurà un total de 178 de lectius. Ho va concretar la secretària general d'Educació, Patrícia Gomà, que va assenyalar que la proposta "s'adequa a la normativa". "Estem en el marc dels dies que determina la norma, i quedarà mirar dies concrets com les vacances de Nadal, Setmana Santa i els quatre dies de lliure disposició", va insistir.

Pel que fa al final de curs, acabarà el 21 de juny per a infantil, primària, ESO i FP bàsica i el 17 per a batxillerat, FP i ensenyaments professionals d'arts plàstiques i disseny. En aquest últim cas, del 18 al 21 hi haurà les avaluacions extraordinàries.

Diari de Terrassa

TERRASSA

Un enginyer elèctric a qui seguir el corrent

Sergi Estapé

31 de març de 2023

Rubén Lijó, un exalumne de l'Eseiaat, ha aconseguit 150.000 subscriptors i 4,5 milions de visualitzacions amb vídeos a Youtube sobre l'enginyeria elèctrica

RUBÉN LIJÓ ÉS CONSULTOR A L'EMPRESA HITACHI I ESTÀ ESTUDIANT EL DOCTORAT A LA UNIVERSIDAD DE LA LAGUNA / ALBY MARTÍN

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TEMES: RUBÉN LIJÓ, UPC

Economia

‘Sígueme la corriente’: el canal de un exalumno de ESEIAAT triunfa en YouTube

Rubén Lijó ha conseguido 150.000 subscriptores y 4,5 millones de visualizaciones con videos sobre ingeniería eléctrica

Laura Gómez Alcalà
02/04/2023 09:35

Un exalumno de la Escuela Superior de Ingenierías Industrial, Aeroespacial y Audiovisual de Terrassa (ESEIAAT) de la Universitat Politècnica de Catalunya (UPC) triunfa a la plataforma de YouTube con el canal divulgativo de ingeniería eléctrica ‘Sígueme la corriente‘. Rubén Lijó, estudiando de doctorado de La Laguna, ha conseguido un total de 150.000 subscriptores y 4,5 millones de visualizaciones con videos sobre el electromagnetismo o los circuitos trifásicos, entre otros conceptos cruciales de asignaturas del grado de Ingeniería Eléctrica. Sus videos han contribuido a potenciar la motivación del estudiante, según afirma el profesor del ESEIAAT, Ricard Horta, que ha colaborado en su producción.

El impacto de los videos didácticos en la formación universitaria es muy positivo. Así lo confirma el artículo publicado en la revista científica de referencia ‘IEEE Acces’ escrito por el mismo Rubén Lijó, los tutores de su tesis doctoral Eduardo Quevedo y José Juan Castro de la Universidad las Palmas de Gran Canaria. El artículo toma como ejemplo, precisamente, el canal ‘Sígueme la Corriente’ y desgrana paso a paso la experiencia didáctica del canal aplicado a la asignatura de Máquinas Eléctricas.

‘Sígueme la corriente’, un nuevo método para motivar los alumnos

Los profesores recopilaron datos de los tres cursos académicos marcados por la COVID, a través de encuestas y entrevistas, e incorporaron algunos conceptos claves del grado, **como por ejemplo el electromagnetismo, o los circuitos trifásicos**. Los videos de Lijó, que compagina el doctorado con su trabajo como consultor a la empresa Hitachi, han conseguido que la motivación de los estudiantes aumente y «su interés por la asignatura es demostrable y muy satisfactorio» afirma Huerta.

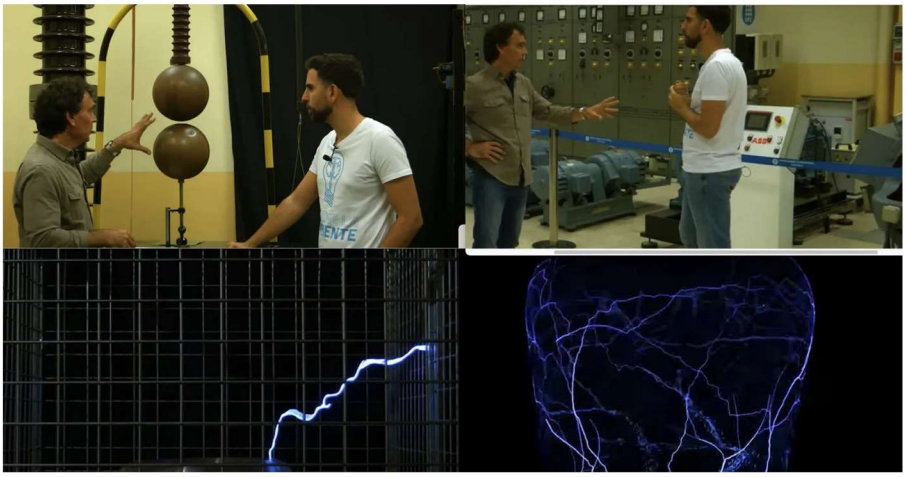
Videos para reforzar el grado al ESEIAAT

Según los cuatro autores del artículo y de la experiencia didáctica, “los videos de ‘Sígueme la Corriente’ han mostrado tener un efecto mitigador de algunos de los impactos negativos principales durante la pandemia, porque han contribuido al reforzamiento de la perspectiva global del grado de Ingeniería Eléctrica, gracias a la conexión conceptual de las asignaturas.”

Societat

VÍDEO El youtuber de l'enginyeria elèctrica té ADN de Terrassa

L'enginyer elèctric Rubén Lijó, format a l'ESEIAAT, és l'editor, productor i realitzador de "Sígueme la corriente"



Joan Manel Oller
26/03/2024 11:15

L'enginyer elèctric Rubén Lijó, format a l'Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa (ESEIAAT) de la Universitat Politècnica de Catalunya – BarceolonaTech (UPC), és l'editor, productor i realitzador de *'Sígueme la corriente'*, un canal de YouTube que divulga l'enginyeria elèctrica i que compta amb més de 170.000 seguidors i 5,5 milions de visualitzacions. 'Experimentando con arcos eléctricos' és el nou vídeo que publica, gravat íntegrament als laboratoris de l'ESEIAAT.

Lijó i Ricard Horta expliquen d'una manera divulgativa les claus de l'alta tensió

Arcs elèctrics, descàrregues electrostàtiques, el funcionament de les bobines de Tesla, la gàbia de Faraday o l'efecte corona són alguns dels fenòmens elèctrics més espectaculars que explica a 'Experimentando con arcos eléctricos" del canal de You Tube "Sigueme la corriente'.

També s'ensenya com funciona tota la cadena de valor de l'electricitat

Lijó i el professor del Departament d'Enginyeria Elèctrica de la UPC Ricard Horta expliquen d'una manera divulgativa les claus de l'alta tensió. També s'ensenya com funciona tota la cadena de valor de l'electricitat, des de la seva generació, passant per la distribució, el transport i finalment el consum.

Lijó i Horta subratllen la importància que ha adquirit l'energia elèctrica a l'actualitat i com d'estratègic és per a la societats comptar amb professionals de l'enginyeria en aquest àmbit. "El món és elèctric, i cada cop ho serà més. Per afrontar aquest nou paradigma cal una formació de qualitat fins arribar a una especialització d'alt nivell, tot integrant a la universitat el que ara es fa a la indústria de l'energia elèctrica", afirma Horta.

Lijó fa èmfasi en l'especialització a l'ESEIAAT en alta tensió i sistemes de potència. "**Aquí es pot aprendre a dissenyar línies d'alta tensió, supervisar sistemes elèctrics o integrar a la xarxa elèctrica sistemes d'energia renovable. Estem vivint un canvi de paradigma energètic i l'electricitat és la protagonista d'aquest canvi**".

Ruben Lijó és un enginyer elèctric canari que compagina la seva feina de consultoria en energia elèctrica i els estudis de doctorat a la Universidad de La Laguna amb la divulgació científica.

Nou vídeo de "Sígueme la corriente" gravat a l'ESEIAAT de la UPC
https://www.youtube.com/watch?v=cE6CX4_B_2w

Article a la revista IEEE Access

https://ieeexplore.ieee.org/document/10050506

Terrassa

El youtuber Ruben Lijó publica un nou vídeo gravat íntegrament a l'ESEIAAT

26/03/2024 1:09 PM / SOCIETAT / REDACCIÓ

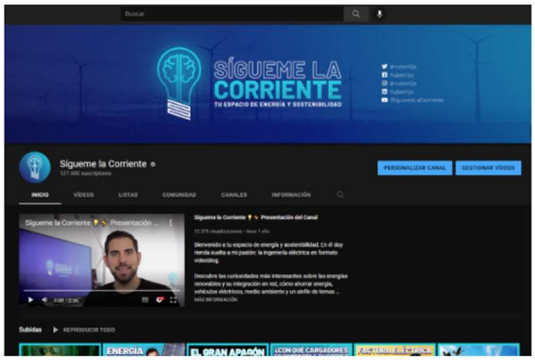
L'enginyer elèctric Rubén Lijó, format a l'Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa (ESEIAAT) de la UPC, és l'editor, productor i realitzador de 'Sígueme la corriente'. **Aquest canal de YouTube divulga l'enginyeria elèctrica** i compta amb més de 170.000 seguidors i 5,5 milions de visualitzacions.

'Experimentando con arcos eléctricos' és el nou vídeo que publica. Ha estat gravat íntegrament als laboratoris de l'ESEIAAT. Compta amb la participació del professor del Departament d'Enginyeria Elèctrica de la UPC **Ricard Horta**.

Lijó i Horta expliquen **d'una manera molt divulgativa** les claus de l'alta tensió. També dediquen alguns minuts a mostrar com funciona tota la cadena de valor de l'electricitat. A més, subratllen a les seves intervencions la importància que ha adquirit l'energia elèctrica en l'actualitat i com d'estratègic és per a la societats comptar amb professionals de l'enginyeria en aquest àmbit.

La ULPGC lidera un estudio sobre el uso de materiales audiovisuales como recurso pedagógico en las enseñanzas STEM

04 FEB 2022



- ***De 912 encuestados, preuniversitarios, universitarios y profesionales señalan mayoritariamente que Youtube es muy útil para entender conceptos abstractos***
- ***Aunque el uso fundamental de los canales de YouTube sea para entretenimiento, una amplia mayoría de usuarios también emplea esta herramienta como apoyo educativo***

El investigador **Rubén Lijó Sánchez**, consultor técnico en la empresa de ingeniería Hitachi y doctorando de la Universidad de La Laguna, y sus directores de Tesis, **Eduardo Quevedo Gutiérrez**, profesor del Departamento de Matemáticas e investigador en el **Instituto Universitario de Microelectrónica Aplicada** de la ULPGC, y **José Juan Castro Sánchez**, profesor del Departamento de Psicología, Sociología y Trabajo Social de la ULPGC, en colaboración con **Ricard Horta Bernus**, profesor del Departamento de Ingeniería Eléctrica de la Universitat Politècnica de Catalunya, publican el artículo de investigación titulado '***Evaluación de la percepción de los usuarios de un canal de YouTube de ingeniería eléctrica sobre su valor educativo actual y potencial***' en la revista especializada **IEEE Access**.

El artículo plantea la posibilidad de que los **canales de YouTube de divulgación científica formen parte activa en el proceso de formación en enseñanzas STEM** (siglas en inglés de Ciencia, Tecnología, Ingeniería y Matemáticas) y evidencia cómo, aunque el uso fundamental de los canales de YouTube sea para entretenimiento, una amplia mayoría de usuarios también emplea esta herramienta como apoyo educativo.

Los autores parten de que los estudios de estas disciplinas están plagados de conceptos abstractos, cuya comprensión supone un reto para el estudiantado. Esto, sumado a las situaciones de educación a distancia, cada vez más frecuentes a raíz del impacto de la pandemia del coronavirus, agrava la dificultad, ya que crean situaciones de aislamiento o entornos desfavorables para el aprendizaje.

En este contexto, los **materiales audiovisuales han demostrado ser una herramienta de apoyo útil para la docencia**, fomentando mejoras en la retención de conceptos a largo plazo y su comprensión. Por ello, los vídeos de divulgación científica disponibles en YouTube podrían ser una herramienta útil para complementar a la enseñanza de disciplinas STEM.

Cuestionario a 912 participantes

Para demostrarlo, los investigadores tomaron como ejemplo el **canal de Ingeniería Eléctrica 'Sígueme la Corriente'**, desarrollado en Canarias, facilitando un cuestionario a sus seguidores y obteniendo una **muestra de 912 participantes**, con la finalidad de evaluar qué tipo de uso hacen de los vídeos del canal, si entretenimiento o educativo, qué percepción tienen respecto a métricas clave para su integración en entornos educativos, y qué opinión presentan respecto a la integración de vídeos en educación.

Los resultados evidencian que, aunque el canal haya sido creado para atender a una necesidad de entretenimiento, **existe un elevado uso pedagógico del mismo (72.7%)**, asociado principalmente al perfil de estudiantes preuniversitarios, de los que el 80.8% contestaron positivamente.

Estudiantes universitarios y profesionales del sector eléctrico también hacen uso educativo del canal con frecuencias respectivas de 73.3% y 78.9%, según la encuesta. Muchos participantes (82.4%) coinciden en que la selección de temas del canal coincide con sus intereses. Asimismo, la mayoría de encuestados (91.6%) coinciden en que el canal muestra un nivel técnico adecuado para la comprensión de conceptos.

Por lo tanto, el estudio ha evidenciado que, aunque el **uso fundamental de los canales de divulgación científica en YouTube sea para entretenimiento, una amplia mayoría de usuarios también emplea esta herramienta como apoyo educativo**. Esta conclusión puede servir a los creadores de contenido de YouTube como evidencia para comenzar a desarrollar vídeos divulgativos específicamente dirigidos a las aulas.

Esta investigación nace fruto de la **colaboración entre la Universidad de Las Palmas de Gran Canaria, la Universidad de La Laguna y la Universitat Politècnica de Catalunya**. Se enmarca en el desarrollo de la tesis doctoral de su autor principal, **Rubén Lijó**, titulada ***'Implicaciones del uso de materiales audiovisuales de divulgación científica como recurso pedagógico en contextos científico-tecnológicos'***.

La ULPGC lidera un estudio de integración de vídeos didácticos para mejorar la enseñanza de ingeniería

30 MAR 2023

Los autores concluyen que la integración de vídeos didácticos en el aula tiene un impacto muy positivo en el alumnado

El investigador **Rubén Lijó Sánchez**, doctorando de la Universidad de La Laguna, y sus directores de tesis, **Eduardo Quevedo Gutiérrez**, profesor del Departamento de Matemáticas e investigador en el **Instituto Universitario de Microelectrónica Aplicada** de la ULPGC y **José Juan Castro Sánchez**, profesor del Departamento de Psicología, Sociología y Trabajo Social de la ULPGC, en colaboración con **Ricard Horta Bernus**, profesor del Departamento de Ingeniería Eléctrica de la **Universitat Politècnica de Catalunya**, publican el artículo de investigación titulado **"Impacto de los Vídeos Didácticos de Ingeniería Eléctrica durante la Enseñanza a Distancia de Emergencia"**, en la revista especializada **IEEE Access**. Este trabajo se enmarca en el desarrollo de la tesis doctoral de su autor principal, Rubén Lijó, titulada **"Implicaciones del uso de materiales audiovisuales de divulgación científica como recurso pedagógico en disciplinas STEM"**.

El artículo toma el testigo de la publicación previa **"Evaluación de la percepción de los usuarios de un canal de YouTube de ingeniería eléctrica sobre su valor educativo actual y potencial"**, en la que se estimó el valor educativo, a partir de una muestra de 912 participantes, de un canal de YouTube de divulgación sobre Ingeniería Eléctrica (**"Sígueme la Corriente"**, desarrollado en Canarias por el autor principal de la investigación). El estudio avaló la utilidad educativa del canal, aplicable como apoyo para la comprensión de conceptos abstractos presentes en disciplinas de Ciencia, Tecnología, Ingeniería y Matemáticas (STEM por sus siglas en inglés).

A partir de ahí, y para este segundo artículo, se puso el canal a disposición de la asignatura "Máquinas Eléctricas I" en la Escuela Superior de Ingenierías Industrial, Aeroespacial y Audiovisual de Terrassa de la Universitat Politècnica de Catalunya; esta asignatura es la primera de especialidad eléctrica a la que accede el alumnado, tras haber estudiado otras asignaturas comunes junto a estudiantes de otras disciplinas de ingeniería.

En esta asignatura, se ha detectado la necesidad de reforzar los conceptos específicos de electromagnetismo y circuitos trifásicos, cruciales para más de un tercio de las asignaturas del Grado en Ingeniería Eléctrica. Mediante una serie de 9 vídeos didácticos especialmente diseñados con este propósito en el canal, se pretende mitigar el impacto negativo de la situación de Enseñanza a Distancia de Emergencia (ERL por sus siglas en inglés) impuesto por la covid-19. Además, se tuvo por objetivo evaluar en qué medida estos vídeos contribuyeron a potenciar la motivación del alumnado y su interés por la asignatura.

Los resultados evidencian que la integración de vídeos didácticos en el aula es eminentemente positiva, en especial para el aprendizaje conceptual y el rendimiento académico, así como en un incremento de la motivación e interés del alumnado por la asignatura.

Particularmente, en la situación de ERL, los vídeos han mostrado tener un efecto mitigador de algunos de sus principales impactos negativos. Además, desde un punto de vista enfocado a la experiencia del alumnado y el desarrollo de su conocimiento completo de la titulación, la estructura propuesta de vídeos didácticos ha mostrado contribuir al refuerzo de la perspectiva global del Grado de Ingeniería Eléctrica, gracias a la conexión conceptual de sus asignaturas. Y, en último lugar, el enfoque práctico de los vídeos y el hecho de que sean desarrollados por un profesional activo del sector son factores que contribuyen a que el alumnado adquiera una perspectiva práctica de la titulación, descubriendo de primera mano las aplicaciones profesionales de sus competencias en la industria.

Dos investigadores de la ULPGC ofrecen pautas en The Conversation para escoger vídeos adecuados con fines educativos

07 MAR 2024

Eduardo Quevedo y José Juan Castro valoran los aspectos clave para aliviar la carga cognitiva mediante recursos audiovisuales

La plataforma de divulgación **The Conversation** publica el artículo **"Cómo seleccionar vídeos adecuados para uso educativo"**, que firman los investigadores de la ULPGC **Eduardo Quevedo** (docente en el área de Didáctica de la Matemática) y **José Juan Castro** (docente de Psicología), junto al investigador predoctoral de la ULL **Rubén Lijó**, y en el que ofrecen pautas para escoger los mejores vídeos cuando se quiera que éstos funcionen con un uso educativo, dado que, según se desprende de su trabajo, estos recursos audiovisuales se emplean de forma constante en las aulas, incluso cuando no han sido creados con ese fin.

Los autores parten del concepto de la *"carga cognitiva esencial"*, definida en la teoría cognitiva del aprendizaje multimedia como la carga "relacionada con el procesamiento de la información para crear representaciones mentales en la memoria de trabajo durante el proceso de aprendizaje. Es la carga cognitiva determinada por la dificultad del contenido a procesar. Por lo tanto, esta carga cognitiva aumenta cuanto más compleja y abstracta sea la disciplina de estudio".

Para enfrentar esa carga cognitiva, los vídeos deben ser un apoyo visual durante las explicaciones, por lo que tendrán preferencia aquellos que integren animaciones y gráficos para ilustrar los conceptos, favoreciendo "la transmisión de la información a través del doble canal auditivo y visual".

Por otra parte, también hacen referencia a la *"carga cognitiva externa"*, que está relacionada con la presentación de la información y las posibles distracciones asociadas, como explicaciones demasiado largas, recursos visuales no atractivos, un estilo comunicativo no adecuado o una mala calidad del propio producto audiovisual.

Otro de los parámetros en los que se debe prestar atención es la duración, si bien no es un parámetro absoluto porque la complejidad del tema influirá en cuánto puede llegar a durar. En general se aconseja entre 5 y 15 minutos.

El tercer concepto que abordan los autores es la *"carga cognitiva relevante"*, la quie se refiere a "la vinculación de la nueva información con la existente en la memoria a largo plazo". Por ello, aconsejan dar prioridad a los vídeos que "vinculen los contenidos explicados con conceptos previos de la misma disciplina, facilitando la contextualización del nuevo conocimiento y fomentando, así, el procesamiento generativo", y mejor aún si forman parte de una serie que pueda reproducirse de forma secuencial.

Las conclusiones de las investigaciones llevadas a cabo por los autores se plasmaron en el **canal de YouTube "Sígueme la corriente"**, con la creación de contenido específico para estudiantes de ingeniería eléctrica, que tuvo una buena acogida entre el alumnado, favoreciendo "el aprendizaje conceptual en áreas complejas y abstractas, y contribuyó al rendimiento académico y la motivación de los alumnos".

Los autores consideran que tener en cuenta estas investigaciones puede ser de mucha utilidad tanto para los docentes como para los creadores de contenido, que a su faceta divulgativa pueden sumar la educativa.

The Conversation España es el principal canal de divulgación del conocimiento que emana de las universidades. La ULPGC se adhirió en febrero de 2020 a esta plataforma, tal y como se ha auspiciado desde la CRUE-Universidades españolas. Los investigadores e investigadoras de la ULPGC han publicado más de 180 artículos en este canal. The Conversation cuenta con ediciones en Estados Unidos, Reino Unido, Canadá, Francia, Indonesia y África, además de la edición en español.

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- **Otros artículos en The Conversation de docentes de la ULPGC**
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ULL y ULPGC estudian el uso de materiales audiovisuales como recurso pedagógico en las enseñanzas STEM

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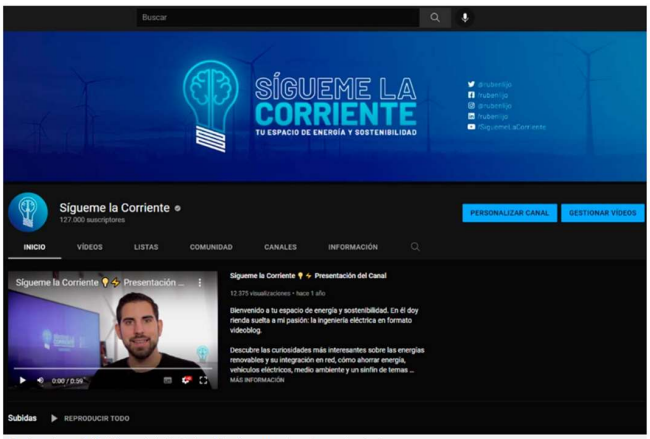


Captura de pantalla del canal de YouTube utilizado como ejemplo para le estudio.

El investigador Rubén Lijó Sánchez, consultor técnico en la empresa de ingeniería Hitachi y doctorando de la Universidad de La Laguna, y sus directores de Tesis, Eduardo Quevedo Gutiérrez, profesor del Departamento de Matemáticas e investigador en el Instituto Universitario de Microelectrónica Aplicada, y José Juan Castro Sánchez, profesor del Departamento de Psicología, Sociología y Trabajo Social, ambos de la universidad de Las Palmas de Gran Canaria, en colaboración con Ricard Horta Bernus, profesor del Departamento de Ingeniería Eléctrica de la Universitat Politècnica de Catalunya, han publicado el artículo de investigación 'Evaluación de la percepción de los usuarios de un canal de YouTube de ingeniería eléctrica sobre su valor educativo actual y potencial' en la revista especializada IEEE Access.

El artículo plantea la posibilidad de que los canales de YouTube de divulgación científica formen parte activa en el proceso de formación en enseñanzas STEM (siglas en inglés de Ciencia, Tecnología, Ingeniería y Matemáticas) y evidencia cómo, aunque el uso fundamental de los canales de YouTube sea para entretenimiento, una amplia mayoría de usuarios también emplea esta herramienta como apoyo educativo.

Los autores parten de que los estudios de estas disciplinas están plagados de conceptos abstractos, cuya comprensión supone un reto para el estudiantado. Esto, sumado a las situaciones de educación a distancia, cada vez más frecuentes a raíz del impacto de la pandemia del coronavirus, agrava la dificultad, ya que crean situaciones de aislamiento o entornos desfavorables para el aprendizaje.

En este contexto, los materiales audiovisuales han demostrado ser una herramienta de apoyo útil para la docencia, fomentando mejoras en la retención de conceptos a largo plazo y su comprensión. Por ello, los vídeos de divulgación científica disponibles en YouTube podrían ser una herramienta útil para complementar a la enseñanza de disciplinas STEM.

Cuestionario a 912 participantes

Para demostrarlo, los investigadores tomaron como ejemplo el canal de Ingeniería Eléctrica 'Sígueme la Corriente', desarrollado en Canarias, facilitando un cuestionario a sus seguidores y obteniendo una muestra de 912 participantes, con la finalidad de evaluar qué tipo de uso hacen de los vídeos del canal, si entretenimiento o educativo, qué percepción tienen respecto a métricas clave para su integración en entornos educativos, y qué opinión presentan respecto a la integración de vídeos en educación.

Los resultados evidencian que, aunque el canal haya sido creado para atender a una necesidad de entretenimiento, existe un elevado uso pedagógico del mismo (72.7%), asociado principalmente al perfil de estudiantes preuniversitarios, de los que el 80.8% contestaron positivamente.

Estudiantes universitarios y profesionales del sector eléctrico también hacen uso educativo del canal con frecuencias respectivas de 73.3% y 78.9%, según la encuesta. Muchos participantes (82.4%) coinciden en que la selección de temas del canal coincide con sus intereses. Asimismo, la mayoría de encuestados (91.6%) coinciden en que el canal muestra un nivel técnico adecuado para la comprensión de conceptos.

Por lo tanto, el estudio ha evidenciado que, aunque el uso fundamental de los canales de divulgación científica en YouTube sea para entretenimiento, una amplia mayoría de usuarios también emplea esta herramienta como apoyo educativo. Esta conclusión puede servir a los creadores de contenido de YouTube como evidencia para comenzar a desarrollar vídeos divulgativos específicamente dirigidos a las aulas.

Esta investigación nace fruto de la colaboración entre la Universidad de Las Palmas de Gran Canaria, la Universidad de La Laguna y la Universitat Politècnica de Catalunya. Se enmarca en el desarrollo de la tesis doctoral de su autor principal, Rubén Lijó, titulada 'Implicaciones del uso de materiales audiovisuales de divulgación científica como recurso pedagógico en contextos científico-tecnológicos'.

Archivado en: Destacado, Investigación, Portada ULL

Etiquetas: contenidos audiovisuales, recursos pedagógicos, STEM, YouTube

Un 'alumni' de la ESEIAAT de la UPC triunfa en YouTube con 'Sígueme la Corriente', un canal divulgativo de Ingeniería Eléctrica

Descargar

Portada de un vídeo de 'Sígueme la Corriente', con Rubén Lijó

El impacto de los vídeos didácticos en la formación universitaria de la Ingeniería Eléctrica es muy positivo, según se desprende de un artículo publicado en la revista científica de referencia 'IEEE Acces', escrito por Rubén Lijó, 'alumni' de la ESEIAAT de la UPC, junto con el profesor de este centro Ricard Horta, y otros dos profesores de la Universitat de las Palmas de Gran Canaria. El artículo toma como ejemplo el canal de YouTube 'Sígueme la Corriente', creado por Rubén Lijó.

31/03/2023

Desde hace años, y a medida que la plataforma de YouTube ha ido ganando popularidad, los y las *youtuber* han cobrado importancia como nueva figura comunicativa. Son innumerables las temáticas de los videos que millones de personas visualizan en este canal y que han hecho célebres, e incluso millonarios, a los creadores de estos contenidos audiovisuales.

Ahora, un *alumni* de la Escuela Superior de Ingenierías Industrial, Aeroespacial y Audiovisual de Terrassa (ESEIAAT) de la **Universitat Politècnica de Catalunya - BarcelonaTech (UPC)**, arrasa en YouTube con su canal de divulgación tecnológica 'Sígueme la Corriente'. Se trata de **Rubén Lijó**, consultor en la empresa Hitachi y estudiante de doctorado en la Universidad de la Laguna, que ha logrado hacer de la Ingeniería Eléctrica un tema de máximo interés, con 150.000 suscriptores y 4,5 millones de visualizaciones de sus vídeos.

Rubén Lijó, junto con los tutores de su tesis doctoral, **Eduardo Quevedo** y **José Juan Castro** –ambos profesores de la Universidad de Las Palmas de Gran Canaria–, y Ricard Horta –profesor de la ESEIAAT de la UPC–, han publicado un artículo en la revista científica de referencia *IEEE Acces* titulado 'Impact of Electrical Engineering Didactic Videos During Emergency Remote Learning' ('Impacto de los vídeos didácticos de Ingeniería Eléctrica durante la enseñanza a distancia de emergencia'). El artículo desgrana paso a paso la experiencia didáctica del uso del canal creado por Rubén Lijó aplicado a la asignatura de Máquinas Eléctricas por parte del profesor Horta, durante la pandemia por COVID.

Según explica Ricard Horta, **"habíamos detectado la necesidad de reforzar algunos conceptos como el electromagnetismo o los circuitos trifásicos, que son cruciales para una tercera parte de las asignaturas del** grado en Ingeniería Eléctrica **. El canal 'Sígueme la Corriente' contiene nueve vídeos didácticos especialmente diseñados para estos dos conceptos"**.

Pero, ¿en qué medida estos vídeos han contribuido a potenciar la motivación del estudiantado? Tal y como se desprende del artículo publicado, los profesores recopilaron datos de los tres cursos académicos marcados por el COVID, a través de encuestas y entrevistas. **"Los resultados evidencian que integrar vídeos didácticos en el aula es muy positivo, sobre todo en lo que se refiere al aprendizaje conceptual y el rendimiento académico. El impacto sobre la motivación de los estudiantes y el aumento de su interés por la asignatura es demostrable y muy satisfactorio"**, afirma Horta.

En el estudio, realizado con una muestra compuesta por 157 estudiantes de entre 18 y 20 años, los investigadores evalúan la variación de la percepción de los estudiantes sobre la calidad de la educación mientras dura el experimento. Con este fin, los estudiantes respondieron a un cuestionario basado en la encuesta validada de Evaluaciones de los Estudiantes de la Calidad Educativa (SEEQ) para la educación superior, que se compone de 32 preguntas estructuradas en nueve factores. Después, cuantificaron la variación de las calificaciones obtenidas, comparando la nota final entre los dos grupos experimentales y el grupo control.

Por último, evaluaron más profundamente la afectación de los vídeos sobre la motivación y el compromiso de los estudiantes a lo largo del curso. Esta evaluación cualitativa se ha realizado mediante una entrevista estructurada para comprender mejor y contrastar los anteriores resultados obtenidos a través de la encuesta SEEQ y el rendimiento académico. La estructura de la entrevista se ha basado en las respuestas deducidas de preguntas como la cantidad de vídeos visualizados, el tipo de uso de los vídeos (satisfacción de la curiosidad, preparación de exámenes, etc.), el impacto de los vídeos en la motivación y el interés por el tema, la relevancia de la identidad del creador de contenidos (profesor versus profesional en la materia) o las implicaciones de los vídeos propuestos como complemento didáctico.

Según los autores del artículo y la experiencia didáctica, **"los vídeos de 'Sígueme la Corriente' han mostrado tener un efecto mitigador de algunos de los principales impactos negativos durante la pandemia, porque han contribuido a reforzar la perspectiva global del grado en Ingeniería Eléctrica, gracias a la conexión conceptual de las asignaturas"**.

Tal y como concluye Ricard Horta, **"el enfoque práctico de los vídeos y el hecho de que sean desarrollados por un profesional activo del sector son factores que contribuyen a que el estudiantado adquiera una perspectiva práctica de la titulación, descubriendo de primera mano las aplicaciones profesionales de sus competencias en la industria"**.

Esta investigación, publicada por *IEEE Acces*, nace fruto de la colaboración entre la Universidad de Las Palmas de Gran Canaria, la Universidad de La Laguna y la UPC, y se enmarca en el desarrollo de la tesis doctoral del autor principal, Rubén Lijó, titulada 'Implicaciones del uso de materiales audiovisuales de divulgación científica como recurso pedagógico en disciplinas STEM'.

Más información

- Canal de YouTube 'Sígueme la Corriente'
- Artículo 'Impact of Electrical Engineering Didactic Videos During Emergency Remote Learning', *IEEE Acces*

Un exalumne de l'ESEIAAT de la UPC triomfa a YouTube amb 'Sígueme la corriente', un canal divulgatiu d'enginyeria elèctrica

L'impacte dels vídeos didàctics en la formació universitària de l'Enginyeria Elèctrica és molt positiu, segons es desprèn d'un article publicat a la revista científica de referència 'IEEE Acces' escrit per Rubén Lijó, Eduardo Quevedo, Juan José Castro i Ricard Horta. L'article pren com a exemple el canal de YouTube 'Sígueme la Corriente' creat per Rubén Lijó, exalumne de l'ESEIAAT de la UPC, que actualment compagina el seu treball de consultor amb la realització de la tesi doctoral a la Universidad de la Laguna. El professor de l'ESEIAAT de la UPC Ricard Horta ha col·laborat en la producció d'aquests vídeos que ha fet servir com a material didàctic durant la pandèmia, en l'assignatura de Màquines Elèctriques, amb resultats molt positius.

Des de fa anys, i a mida que la plataforma de YouTube s'ha anat fent més popular, la figura del YouTuber ha cobrat importància com a nova figura comunicativa. Són innumerables les temàtiques que milions de persones visualitzen en aquest canal i que han fet cèlebres, i fins i tot milionaris, als creadors d'aquests continguts audiovisuals de consum massiu.

Ara, un exalumne de l'Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa (ESEIAAT) de la Universitat Politècnica de Catalunya - BarcelonaTech (UPC) arrasa a YouTube amb el seu canal de divulgació tecnològica anomenat 'Sígueme la Corriente'. Es tracta de Rubén Lijó, consultor a l'empresa Hitachi i estudiant de doctorat a la Universidad de la Laguna, que ha aconseguit fer de l'enginyeria elèctrica un tema de màxim interès, amb 150.000 subscriptors i 4,5 milions de visualitzacions dels seus vídeos.

Rubén Lijó, estudiant de doctorat a la Universidad de La Laguna, juntament amb els tutors de la seva tesi doctoral Eduardo Quevedo, José Juan Castro (tots dos professors de la Universitat de Las Palmas de Gran Canaria), i amb la col·laboració de Ricard Horta (professor de l'ESEIAAT de la UPC), han publicat un article a la revista de referència *IEEE Acces* titulat 'Impact of Electrical Engineering Didactic Videos During Emergency Remote Learning' (Impacte dels vídeos didàctics d'Enginyeria Elèctrica durant l'ensenyament a distància d'emergència'. L'article desgrana pas a pas l'experiència didàctica de la utilització del canal creat per Rubén Lijó aplicat a l'assignatura de Màquines Elèctriques per part del professor Horta durant el període de pandèmia per la COVID.

Segons explica el mateix Ricard Horta, **"havíem detectat la necessitat de reforçar alguns conceptes, com ara l'electromagnetisme, o els circuits trifàsics, que són crucials per a una tercera part de les assignatures del grau d'Enginyeria Elèctrica. El canal 'Sígueme la Corriente' conté nou vídeos didàctics especialment dissenyats per a aquests dos conceptes"**.

Però, en quina mesura aquests vídeos han contribuït a potenciar la motivació de l'estudiantat? Tal i com es desprèn de l'article publicat, els professors van recopilar dades dels tres cursos acadèmics marcats per la COVID, a través d'enquestes i entrevistes. **"Els resultats evidencien que integrar vídeos didàctics a l'aula és molt positiu sobretot pel que fa a l'aprenentatge conceptual i el rendiment acadèmic. L'impacte sobre la motivació dels nostres estudiants i l'augment del seu interès per l'assignatura és demostrable i molt satisfactori"**, afirma Horta.

I és que en l'estudi, realitzat amb una mostra composada per 157 estudiants entre 18 i 20 anys, els investigadors avaluen la variació de la percepció dels estudiants sobre la qualitat de l'educació durant la durada de l'experiment. Amb aquesta finalitat, els estudiants van respondre un qüestionari basat en l'enquesta validada d'Avaluacions dels Estudiants de la Qualitat Educativa (SEEQ) per a l'educació superior, que es compon de 32 preguntes organitzades en nou factors. Després, van quantificar la variació de les qualificacions obtingudes comparant la nota final entre els dos grups experimentals i el grup control.

Finalment, van avaluar més profundament l'afectació dels vídeos sobre la motivació i el compromís dels estudiants al llarg del curs. Aquesta avaluació qualitativa s'ha realitzat mitjançant una entrevista estructurada per comprendre millor i contrastar els resultats anteriors obtinguts a través de l'enquesta SEEQ i el rendiment acadèmic. L'estructura de l'entrevista s'ha basat en les respostes deduïdes de preguntes com ara la quantitat de vídeos visualitzats, el tipus d'ús dels vídeos (satisfacció de la curiositat, preparació d'exàmens, etc.), l'impacte dels vídeos en la motivació i l'interès pel tema, la rellevància de la identitat del creador de continguts (professor *versus* professional en la matèria) o les implicacions dels vídeos proposats com a complement didàctic.

Segons els quatre autors de l'article i de l'experiència didàctica, **"els vídeos de 'Sígueme la Corriente' han mostrat tenir un efecte mitigador d'alguns dels impactes negatius principals durant la pandèmia, perquè han contribuït al reforçament de la perspectiva global del grau d'Enginyeria Elèctrica, gràcies a la connexió conceptual de les assignatures**."

Perquè, tal i com conclou Ricard Horta, **"l'enfocament pràctic dels vídeos i el fet que siguin desenvolupats per un professional actiu del sector són factors que contribueixen a fer que l'alumnat adquireixi una perspectiva pràctica de la titulació, descobrint de primera mà les aplicacions professionals de les seves competències en la indústria"**.

Aquesta recerca, publicada per *IEEE Acces,* neix fruit de la col·laboració entre la Universitat de Las Palmas de Gran Canària, la Universitat de La Laguna i la UPC i s'emmarca en el desenvolupament de la tesi doctoral de l'autor principal, Rubén Lijó, titulada 'Implicaciones del uso de materiales audiovisuales de divulgación científica como recurso pedagógico en disciplinas STEM'.

Més informació

- Canal 'Sígueme la Corriente'
- Article a la revista *IEEE Acces:*

Ruben Lijó, el 'youtuber' més seguit d'enginyeria elèctrica, publica un nou vídeo al canal 'Sígueme la corriente'", gravat íntegrament a l'ESEIAAT de la UPC

Ricard Horta i Ruben Lijó al laboratori d'alta tensió de l'ESEIAAT de la UPC

L'enginyer elèctric Rubén Lijó, format a l'Escola Superior d'Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa (ESEIAAT) de la Universitat Politècnica de Catalunya - BarcelonaTech (UPC), és l'editor, productor i realitzador de *'Sígueme la corriente'*, un canal de YouTube que divulga l'enginyeria elèctrica i que compta amb més de 170.000 seguidors i 5,5 milions de visualitzacions. 'Experimentando con arcos eléctricos' és el nou vídeo que publica, gravat íntegrament als laboratoris de l'ESEIAAT.

Arcs elèctrics, descàrregues electrostàtiques, el funcionament de les bobines de Tesla, la gàbia de Faraday o l'efecte corona són alguns dels fenòmens elèctrics més espectaculars que explica i mostra amb tot detall Ruben Lijó al nou vídeo titulat 'Experimentando con arcos eléctricos" del canal de You Tube "Sigueme la corriente'.

Aquest vídeo, gravat íntegrament al laboratori d'alta tensió i altres espais de l'ESEIAAT, compta també amb la participació del professor del Departament d'Enginyeria Elèctrica de la UPC Ricard Horta.

A través d'experiments realitzats al laboratori de la UPC a Terrassa, Lijó i Horta expliquen d'una manera molt divulgativa les claus de l'alta tensió. El vídeo també dedica alguns minuts a mostrar com funciona tota la cadena de valor de l'electricitat, des de la seva generació, passant per la distribució, el transport i finalment el consum.

Lijó i Horta subratllen a les seves intervencions la importància que ha adquirit l'energia elèctrica a l'actualitat i com d'estratègic és per a la societats comptar amb professionals de l'enginyeria en aquest àmbit. "**El món és elèctric, i cada cop ho serà més. Per afrontar aquest nou paradigma cal una formació de qualitat fins arribar a una especialització d'alt nivell, tot integrant a la universitat el que ara es fa a la indústria de l'energia elèctrica**", afirma Horta.

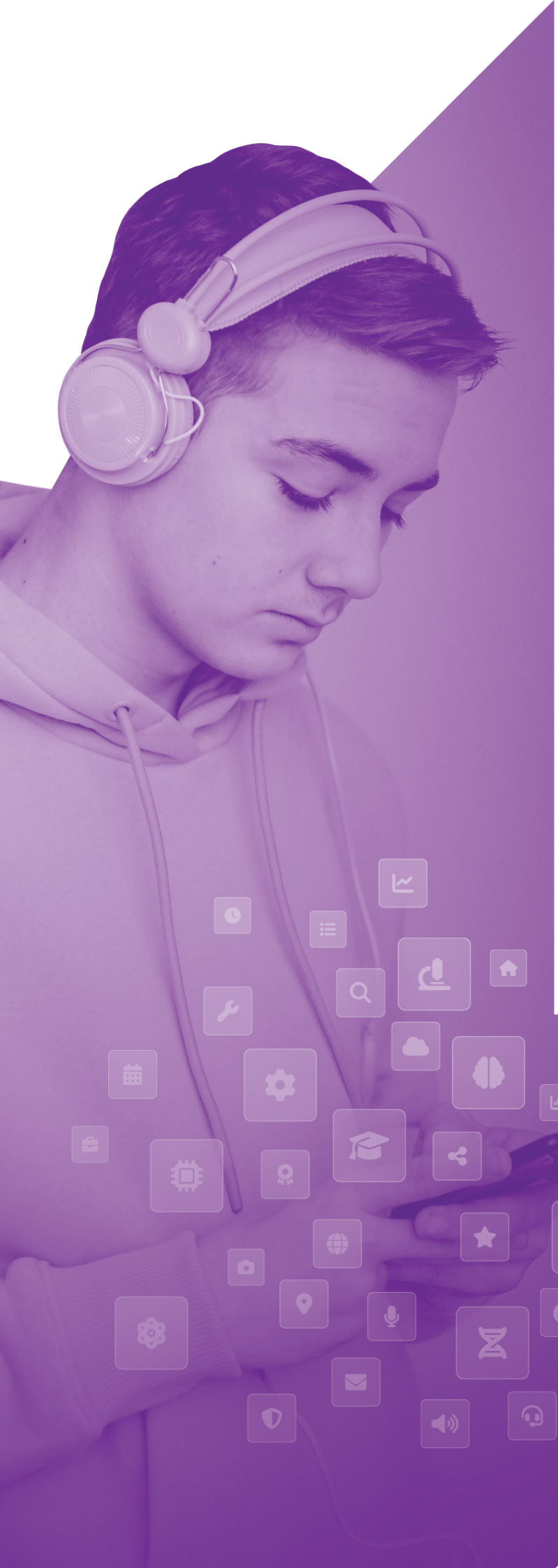
Per la seva part, Lijó fa èmfasi en l'especialització a l'ESEIAAT en alta tensió i sistemes de potència. "**Aquí es pot aprendre a dissenyar línies d'alta tensió, supervisar sistemes elèctrics o integrar a la xarxa elèctrica sistemes d'energia renovable. Estem vivint un canvi de paradigma energètic i l'electricitat és la protagonista d'aquest canvi**", conclou Lijó.

Ruben Lijó és un enginyer elèctric canari que ha rebut part de la seva formació a l'ESEIAAT de la UPC. Lijó compagina la seva feina de consultoria en energia elèctrica i els estudis de doctorat a la Universidad de La Laguna amb la divulgació científica. Amb 170.000 seguidors i més de 5,5 milions de visualitzacions, Rubén Lijó ha aconseguit esdevenir un referent de la divulgació d'aquest àmbit de l'enginyeria.

A més dels seus vídeos, aquest alumni de la UPC a Terrassa també ha realitzat estudis sobre la incidència d'aquest tipus de vídeos didàctics en la motivació dels estudiants. De fet, juntament amb els seus tutors de tesi doctoral Eduardo Quevedo, José Juan Castro (tots dos professors de la Universitat de Las Palmas de Gran Canaria) i amb la col·laboració del mateix Ricard Horta, van publicar un article a la revista de referència IEEE Access titulat '"***Impacto de los vídeos didácticos de ingeniería eléctrica durante la enseñanza a distancia de emergència***', que desgrana l'experiència didàctica de la utilització del canal creat per Rubén Lijó aplicat a l'assignatura Màquines Elèctriques per part del professor Horta durant el període COVID.

Enllaços relacionats

- **Nou vídeo de "Sígueme la corriente" gravat a l'ESEIAAT de la UPC**
- **Article a la revista IEEE Access**
- **Fotografies**



Studies related to the disciplines of Science, Technology, Engineering and Mathematics (STEM) present specific challenges in their teaching and learning process, which are emphasized during Emergency Remote Learning scenarios.

These types of learning challenges are fundamentally related to the wide presence of abstract concepts in their subjects, as well as the difficulty in establishing connections between the different conceptual areas that make up their degrees. In this context, audiovisual resources have proven to be useful as a didactic support in the mitigation of these drawbacks. However, its adequate creation by teachers requires an advanced level of digital competence, as well as a large investment in terms of time and resources. STEM dissemination audiovisual materials widely available on the internet can be useful to fill this gap.

In this line, this doctoral thesis focuses on the study of the pedagogical value of STEM dissemination resources, as well as on the implementation of strategies for their proper integration into formal education.