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Innovative Chemical Engineering Education: Social Media-Enhanced Project-Based Learning Approaches

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Abstract

This study investigates the integration of social media platforms, specifically YouTube and TikTok, as educational tools in Project-Based Learning (PBL) within chemical engineering courses, with a particularly focus on Unit Operations. The research involved seventy-eight students from the Universidad Técnica Particular de Loja across two consecutive semesters (April-August 2022 and October 2022-February 2023). Students were tasked with creating educational videos to communicate complex engineering concepts. YouTube was utilized for longer, detailed explanations, while TikTok was employed for short, engaging content. The results demonstrate the effectiveness of this method in enhancing student engagement and comprehension of both theoretical and practical concepts. Instructors observed substantial improvements in student creativity and digital literacy. Quantitative data, such as average course scores, and qualitative feedback from instructors highlight both the strengths and challenges of leveraging social media as a learning tool. A project evaluation rubric was developed to assess performance across several dimensions, including content mastery, practical application, creativity, and engagement. The study concludes that the combination of PBL with social media platforms creates a dynamic, interactive learning environment that cultivates essential skills for future engineers. However, it also identifies areas for refinement, particularly in terms of effective communication through digital media formats.

Keywords:

Project-Based Learning (PBL);
Higher Education;
Social Media;
Repositories.

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1- Introduction

In the context of education, technological advancements have become a key factor in transforming how knowledge is imparted and acquired, enhancing the overall learning experience. Chemical engineering is no exception, as it continues to evolve to meet the demands of a dynamic and ever-changing industry [1]. Traditional pedagogical strategies have long been complemented—and in some cases replaced—by innovative approaches that leverage the power of the internet and social networks to increase student motivation [2]. Furthermore, modern educational philosophy emphasizes the concept of student motivation. This motivation can be defined as the degree to which students are willing and prepared to devote their energy and cognitive and emotional resources to learning academic tasks related to their subject of study for reasons other than external compulsion. Motivation is widely recognized as a critical factor for learning success, especially when active methodologies such as Project-Based Learning (PBL) are employed. These approaches foster student engagement by aligning academic tasks with real-world applications and intrinsic interests, thereby improving educational outcomes [3–5].

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Project-based learning (PBL) has emerged as a dynamic pedagogical strategy that redefines how knowledge is delivered and skills are acquired [6]. Rooted in the educational philosophy of constructivism, PBL emphasizes active learning where students construct their own mental models. Unlike conventional mass lecture formats, constructivism emphasizes that students learn most effectively when they are actively engaged in generating solutions [7–9]. PBL represents a shift from traditional educational models based on memorization and passive absorption of information. It places students at the centre of their learning journey, transforming them into active participants [10]. By immersing students in real-world challenges and collaborative activities, PBL cultivates critical thinking, problem-solving, and teamwork skills [11]. Rather than simply learning facts and concepts, PBL encourages students to tackle real-world challenges, often through complex, open-ended projects. These projects integrate diverse topics and disciplines, reflecting the rich variety of modern curricula [12].

Several studies have demonstrated that PBL method enhances motivation, deepens understanding, and fosters skills that aligned with real-world demands. The fundamental principle of this method is that students learn more effectively when they are motivated, perceive the relevance of their studies in real world contexts, and are given the autonomy to explore, question, and create [13]. Through this approach, students demonstrate their understanding by producing tangible results in authentic contexts [14]. Increased motivation makes PBL particularly effective in achieving desired learning outcomes [15]. This approach can also lead to a deeper understanding of specific area of knowledge, as students engage more intensely with the subject matter. Recent research supports this claim, showing that PBL fosters meaningful and sustainable learning [16, 17].

An effective and creative strategy to foster greater student engagement and intrinsic motivation in Project-Based Learning (PBL) is leveraging widely adopted social media platforms. These platforms, including YouTube and TikTok, are inherently engaging for current generations [18–21]. In recent years, social media has emerged as an innovative tool for transforming education, including chemical engineering disciplines. The integration of digital resources, particularly educational video repositories, presents a unique opportunity to enhance and amplify the impact of PBL [22]. By combining PBL projects with video content, educators can foster deeper engagement and understanding while addressing inherent challenges [23, 24].

Video repositories, as rich sources of instructional content, introduce compelling visual and auditory dimensions to the learning process. When strategically integrated with PBL, these repositories create a dynamic platform for exploration, discovery, and mastery [22, 25]. Additionally, these resources offer the potential for personalized learning and adaptation of different learning styles [26]. Social media tools play a pivotal role in motivating and engaging students by aligning academic tasks with their preferred digital tools. In terms of collaborative learning, social platforms encourage active participation, self-gratification, and determination, which are key to fostering student-centred and autonomous learning. Furthermore, social media tools align with the connectivism framework, exploring learning through diverse networks and interactions [27–31].

A critical consideration for educators designing enriching learning experiences is the development of essential 21st-century skills [22]. Recent studies highlight the educational potential of platforms such as TikTok and YouTube, displaying their ability to enhance student motivation and engagement while fostering these skills. For instance, TikTok has been effectively used to teach fundamental scientific concepts and laboratory procedures through short, engaging videos, demonstrating its utility as a tool for science communication [32]. Similarly, YouTube, the most widely utilized platform for learning in engineering fields, owes its popularity to its extensive content and user base. However, its effectiveness depends heavily on the quality and reliability of the educational material provided [33]. Moreover, YouTube-assisted instruction has been shown to improve academic performance and attitudes in chemistry classrooms, underscoring its applicability to chemical engineering education [34]. Innovations in teaching methods, particularly in chemical engineering principles courses, further highlight the importance of integrating digital tools to bridge theory and practice while fostering greater student participation [35]. Additionally, TikTok's educational role has been explored through strategies such as using a casual tone and brief video formats, which can be adapted to optimize chemical engineering instruction [36]. These studies collectively emphasize the opportunities and challenges of incorporating social media platforms into education and provide a foundation for exploring innovative approaches to social media-enhanced project-based learning.

In today's educational landscape, chemical engineering students face challenges that extend beyond the complexities of the subject itself, particularly in mastering unit operations—a core component of the curriculum that requires a blend of theoretical knowledge, practical experience, and problem-solving skills [26, 37–39]. As these operations form the foundation of industrial processes, exploring innovative teaching approaches that enhance understanding and engagement. Social media platforms like YouTube and TikTok offer valuable opportunities to connect theoretical concepts with real-world applications, presenting complex engineering topics in an interactive and accessible format. These tools not only foster student motivation and a sense of community but also complement active learning strategies such as project-based learning (PBL), which is widely recognized for improving academic outcomes [40–45]. However, while platforms like YouTube and TikTok show potential for enhancing chemical engineering education by bridging theory and practice, their application in this field remains underexplored, highlighting the need for further research into their role in improving student engagement and learning outcomes [46–52].

This article examines a novel aspect of chemical engineering education: the use of social networks as auxiliary tools for learning unit operations [53]. While social media has been employed for educational purposes in various fields [54], its application in the specialized domain of chemical engineering—particularly for unit operations—represents an exciting frontier. Social media platforms offer diverse formats, including videos, blogs, podcasts, images, and social bookmarking, which can enhance the teaching-learning process [55]. For instance, creating an educational video repository specifically for unit operations offers numerous advantages, as demonstrated in other scientific disciplines [56]. Videos can effectively illustrate abstract concepts and complex processes, improving students' comprehension [27, 55]. Additionally, the accessibility of these resources allows learners to study at their own pace and revisit content as needed to meet individual learning needs [57], By integrating educational video repositories into the teaching-learning process for unit operations, this study explores the intersection of pedagogy and technology, providing improved outcomes for educators and students alike [58-60].

This approach, which integrates Project-Based Learning (PBL) with social media platforms, has potential applications beyond chemical engineering. The use of video creation and digital storytelling can be adapted to various STEM disciplines, such as biology, physics, and environmental science [61, 62], where students could visually demonstrate experiments, model natural phenomena, or explain sustainable practices [63, 64]. These platforms provide a unique opportunity to simplify complex ideas, making them accessible while maintaining academic rigor [32, 65]. Tailored rubrics, discipline-specific examples, and creative storytelling techniques would ensure the methodology aligns with the technical and educational needs of different fields [61]. By extending this approach to other STEM areas, educators could foster critical thinking, enhance engagement, and build transferable digital skills across disciplines [65].

The paper addresses three key questions: How can project-based learning (PBL) combined with social media enhance the learning experience of chemical engineering students, particularly in the context of unit operations? Can the combination of PBL and video repository facilitate with more interactive and effective learning? Does the use of PBL and social networks contribute with the understanding of unit operations? To address these questions, the article is organized into four key sections. The introduction establishes the study's context, highlighting the significance of unit operations in chemical engineering and the educational potential of social media. It also explores constructivism as the foundational framework for PBL and its constructive interaction with digital technologies. The second section outlines the methodology used to design and implement the proposed strategies, detailing the steps and tools employed to achieve the study's objectives. The third section presents and discusses the results, emphasizing the impact of PBL and social media platforms on student learning outcomes in unit operations. Finally, the fourth section offers a comprehensive conclusion, summarizing the findings, discussing their implications for chemical engineering education, and providing recommendations for future research. This study contributes to the scientific literature by examining the integration of information-sharing platforms as innovative educational tools and evaluating their practical applications in enhancing chemical engineering education. It aims to bridge the gap between theory and practice, providing valuable insights for educators and researchers in STEM fields.

2- Material and Methods

2-1- Project Model Canvas (PM Canvas) for PBL Assisted by Social Media Networks

In this study, we employed an adaptation of the Project Model Canvas (PM Canvas), originally proposed by Finocchio Junio in 2014, as a strategic tool for planning and structuring the Project-Based Learning (PBL) methodology [66]. The PM Canvas facilitated the alignment of educational objectives, project design, and practical implementation through the creation of videos on social media platforms. This clear visual framework simplified the management of learning outcomes, resources, and timelines. The PM Canvas proved essential for effectively integrating the PBL methodology into the chemical engineering courses by clearly defining the key elements of the projects and ensuring that academic content and practical work were well-organized. Figure 1 presents the PM Canvas employed in this study.

Courses

The project was implemented within the Unit Operations courses in Chemical Engineering, which include:
Mass and energy balance, Fluid mechanics, Heat transfer, Chemical Kinetic.
The project was conducted over two consecutive semesters: April–August 2022 and October 2022–February 2023.

Assessment learning

Evaluation rubric: developed to assess the video-assisted project based on key criteria, including content mastery, creativity, practical application, and engagement.
Surveyes: administered to evaluate student satisfaction and motivation regarding the impact of video usage on learning outcomes.

Content

Students focus: highlighted real-world problems, to emphasize the practical relevance of chemical engineering topics.
YouTube Projects: focused on detailed practical demonstrations, and explanations of theoretical principles. Applications were showcased through 10-minute videos.
TikTok Projects: short, 60–90 second videos simplifying complex engineering concepts and designed to engage a broader audience.

Risks

- Unequal access to technology for video creation.
- Difficulty in balancing engaging, creative content with academic rigor.
- Challenges in simplifying complex engineering concepts while retaining essential information.

Objectives

The primary objectives of the Project-based learning (PBL) approach, supported by social media networks, were:

- Enhance student's understanding of theoretical principles in Unit Operations courses by applying them through experiments.
- Develop students' communication skills by utilizing social media platforms to present their work.
- Increase student motivation and encourage autonomous learning and teamwork through the collaborative creation of engaging video content.

Problem

The project addressed the challenge of improving students' understanding of both theoretical principles and practical application in Chemical Engineering, specifically in Unit Operations. The goal was to make learning interactive and engaging through practical applications and innovative teaching methods using social media platforms as educational tools.

Schedule

The project was conducted over two academic semesters:
April–August 2022: Focus on creating YouTube videos.
October 2022–February 2023: Focus on producing TikTok videos.
Each semester included phases: project development, presentation and evaluation of videos, and feedback from professors and peers

Success indicators

- Increased student attendance and engagement in both in-person and online classes.
- Improved academic performance, as reflected in higher grades.
- Positive student feedback on the relevance and effectiveness of multimedia content.

Environment

The project was conducted in a hybrid learning environment that combined:

On-campus resources: University laboratories, equipment, and materials for developing YouTube and TikTok projects.

Off-campus flexibility: students utilized settings like their homes or outdoor spaces to simulate real-world chemical engineering processes.

The use of social media platforms as educational tools provided students with flexibility, enabling them to work both on-campus and independently.

Human capital

Participants: seventy-eight students from the Chemical Engineering program at Universidad Técnica Particular de Loja.
Instructor support: professors provided continuous guidance on both the technical and practical aspects, assisting students in balancing creativity with academic rigor.

Processes

The project followed a structured approach:
Stage 1 - Initial planning: development of syllabus design and project guidelines, including instructions on video production requirements.
Stage 2 - Project development: students selected topics, developed projects, and created videos.
Stage 3 – Presentation and Evaluation: students presented their videos during the final evaluation week, followed by detailed feedback from professors and peers.

Figure 1. PM Canvas for PBL assisted by social media networks

2-2- Project Description

The Project-Based Learning (PBL) approach, supported by Social Media Networks (SM), was conducted over two consecutive semesters: April–August 2022 and October 2022–February 2023. The Unit Operations courses—Mass and energy balance, Fluid mechanics, Heat Transfer, Chemical Kinetics—were developed using the Project-Based Learning (PBL) methodology. This project involved seventy-eight chemical engineering students, aged 19 to 21, from the Faculty of Exact and Natural Sciences at the Universidad Técnica Particular de Loja (UTPL). The academic details of the courses involved in this study are provided in Table 1.

Table 1. Description of courses participating in the project

Courses	Students number	Semester
Mass and Energy Balance	18	April–August 2022
Fluid Mechanics	13	October 2022–February 2023
Chemical Kinetics	30	April–August 2022
Heat Transfer	17	October 2022–February 2023

The primary objective was to enable students to apply theoretical concepts by creating of videos using YouTube and TikTok as platforms to present ad communicate their work, while maintaining academic rigor throughout the educational experience. By applying theoretical knowledge to practical contexts, students developed projects that were later showcased in video formats. These videos demonstrated the application of theoretical principles and the real-world implications of chemical engineering concepts, particularly in industrial settings. This video-assisted Project-Based Learning methodology enabled students to develop technical expertise and transferable skills such a communication and digital literacy, which are increasingly important in modern engineering practices.

2-2-1- Technology and Resources Used

No formal technical training on video creation—such as editing, scripting, or storytelling—was provided during this project. This decision was made because the students already demonstrated sufficient familiarity with video production tools through their regular use of social media platforms. Their existing expertise allowed them to focus on creatively and effectively applying their theoretical knowledge to the project. Students were required to create detailed project explanations using YouTube for longer-form content and TikTok for shorter, more engaging content. These platforms were chosen due to their accessibility and familiarity, enabling all participants to engage with the tasks without requiring extensive technical training. Additionally, neither platform required specialized software or paid subscriptions, making them cost-effective and user-friendly.

2-2-2- Stages of Project Implementation

The video-assisted PBL methodology was implemented in two distinct phases.

YouTube video creation (First semester: April–August 2022)

During the first semester, students were guided to plan, develop, and present their technical project using video as the primary medium. The projects illustrated the application of specific theoretical principles covered in the course curriculum. For the final project, students presented 10-minute YouTube videos focusing on the following aspects:

- Selection of a real-world engineering problem related to course topics or fundamental theoretical principles.
- Design and construction of a prototype to solve the problem or demonstrate a practical application.
- Creation of a YouTube video that clearly explained:
    - The theoretical foundations related to the project through a detailed explanation of specific principles.
    - The steps involved in the design and construction of the prototype.
    - The real-world engineering processes demonstrating the application of the application of theoretical concepts.

The stage resulted in the development of audiovisual materials where students demonstrated technical knowledge, connected theory with practice, and effectively presented their findings through digital media. A repository of these videos was created as a resource for the entire Chemical Engineering School.

TikTok Video Creation (Second Semester: October 2022–February 2023)

The second phase focused on creating TikTok videos, with students producing short, visually engaging content (60-90 second). They identified real-life or industrial processes and explained them through the lens of chemical engineering principles. This phase emphasized simplifying complex topics while maintaining academic rigor and developing communication skills using creative storytelling techniques and visual aids to engage a broader audience. Each group focused on:

- Identifying an industrial process that could be explained using chemical engineering principle.
- Demonstrating the application of these principles in everyday or industrial operations.
- Creating engaging, innovative video that captured audience attention with clear explanations and creative visuals.

2-2-3- Project Development

Student engagement was closely monitored throughout the project by incorporating continuous observations and milestone evaluations. These evaluations took place during tutorial sessions, where students provided progress updates, as well as during formal project reviews at each development phase. Instructors assessed engagement through various factors, including active participation, creativity, teamwork, and the timely completion of assigned tasks. Additionally, the feedback exchanges during these sessions offered valuable insights into students' involvement and understanding, allowing for ongoing support and guidance.

The project lasted 16 weeks and was divided into four-week periods.

Week 1-4: A detailed explanation of the project was conducted. Students compiled and summarized principles and theoretical concepts (academic criterion).

Week 5-8: Practical applications of the theory were identified (practical application criterion).

Week 9-12: Innovative approaches presenting content were developed, such as scale models, prototypes, or other physical elements to explain the engineering principle (creativity criterion).

Week 13-16: Compilation and editing of images, narratives, and scripts for the video projects were completed (engagement criterion).

Final YouTube and TikTok videos were presented during the sixteenth week of each semester (April–August 2022 and October 2022–February 2023). Students showcased their work to peers and instructors. This presentation was a significant part of the evaluation, with feedback provided on both the academic content and the effectiveness of the video as an educational tool.

2-2-4- Project Evaluation

Student engagement played a central role in the project evaluation process and was assessed through continuous observation during in-class activities, tutorial sessions, and project presentations. Instructors monitored students' ability to meet deadlines, actively participate in group discussions, and demonstrate steady progress throughout the project phases. This approach not only offered valuable insights into the students' level of engagement but also enabled timely interventions to support their learning and ensure the successful completion of their projects.

The evaluation adhered to UTPL guidelines, allocating 35% of the course grade to theoretical work, 35% to experimental/practical work, and 30% to autonomous learning. The PBL video projects formed part of the autonomous learning component, evaluated continuously across to the four project periods and the grade was assigned in week 16, in each period at least 80% of the criteria had to be met to continue with the next one. Final project assessment, scored out of ten points, were based on a rubric with the following criteria:

- Academic (30%, 3 points): quality of theoretical concept explanation.
- Practical application (30%, 3 points): demonstration of real-world chemical engineering applications in industry.
- Creativity (15%, 1.5. points): innovative approaches to presenting content.
- Engagement (15%, 1.5 points): ability to present a concise, engaging narrative of YouTube and effectively convey complex ideas on TikTok.

In addition to academic evaluation, a survey based on an adaptation of Keller's ARCS Model of Motivation (Attention, Relevance, Confidence, Satisfaction) was used to assess students' motivation and the impact of social media on their learning experience. The Keller Questionnaire (Appendix I) evaluated four main criteria: attention, confidence, relevance and satisfaction.

2-2-5- Evaluation of Academic Results

A mixed-method approach was used, combining quantitative and qualitative analyses. Quantitative analysis was based on average course grades obtained during the project-based learning (PBL) activities using social media platforms (YouTube and TikTok). Student's performance was assessed using the average course grades of the course and a comprehensive grading rubric evaluating key academic competencies:

- Theoretical understanding: mastery of fundamental chemical engineering concepts.
- Practical application: ability to translate theory into practical solutions.
- Creativity: innovation and originality in the presentation of engineering concepts.
- Engagement: effectiveness in maintaining attention and communicating complex ideas in both long-format (YouTube) and short-format (TikTok) videos.

In the qualitative analysis of academic results, an interview with course instructors assessed the clarity and accuracy of theoretical content, the effectiveness of visual representations, creativity, engagement strategies, and the challenges of simplifying complex engineering concepts for TikTok videos. The interview process was designed based on established research emphasizing the importance of clarity in presenting technical content, particularly in video-based learning environments. According to Guo et al. (2014), clear communication of complex concepts, supported by well-structured visuals, plays a critical role in enhancing student comprehension in multimedia learning settings [67]. Additionally, creativity and engagement strategies have been shown to significantly influence student motivation and information retention, as highlighted by Fiorella et al. (2015) [68]. The use of short-form videos presents unique challenges in maintaining academic rigor while condensing complex topics, an issue discussed and supported by research on cognitive load theory [69, 70]. Thus, the interview aimed to collect feedback, providing a deeper insight into both individual and group achievements, and evaluate the positive and negative aspects of the student projects. These research findings as a framework to assess the overall effectiveness of the PBL initiative.

Clarity and accuracy of theoretical content [67].

- *How clearly and accurately did students present the theoretical content in their videos?*

Effectiveness of visual representations in videos [67].

- *How effective were the visual representations in enhancing the understanding of the concepts presented?*

Creativity and engagement strategies [68].

- *How creative and engaging were the students' strategies in presenting complex concepts?*

Challenges in simplifying complex engineering concepts for TikTok videos [69,70].

- *What challenges did students face in simplifying complex engineering concepts for TikTok videos, and how well did they manage them?*

3- Results and Discussions

3-1- Results of a Sample Project

The primary objective of this study was to create educational resources on YouTube and TikTok to support learning in unit operations courses through interactive and engaging content. By harnessing students' creativity and technical knowledge, this approach aimed to enhance understanding and motivate active participation, enabling students to present complex concepts in accessible formats for a broader audience. Figure 2 illustrate the interface of the YouTube video repository, where student projects are systematically organized and accessible, providing a structured platform for reviewing and reinforcing course concepts.

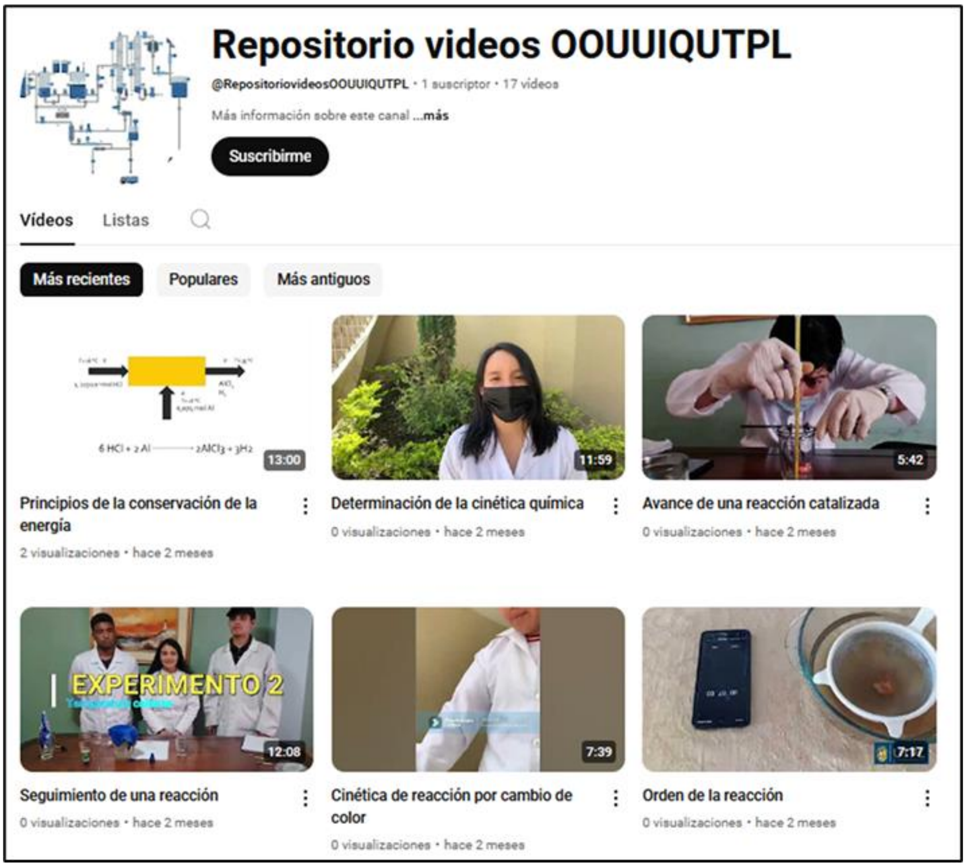

Figure 2. Interface of the YouTube video repository (available on: https://www.youtube.com/@RepositoriovideosOOUUIQUTPL)

One of the feature videos developed by students was titled "Reactions with Catalyst" which explored the impact of sodium chloride as an inorganic catalyst on the rate of a redox reaction between copper sulphate and zinc. This project, conducted in the Chemical Kinetics course, had the following primary objectives: to study and understand the concept of catalysis, identify the type of catalysis occurring during a redox reaction, determine the equilibrium state through observable characteristic changes in reactions in solution (such as metal oxidation and reduction), and calculate the rate of zinc disappearance in both catalysed and non-catalysed reaction.

In the 10-minute video, students demonstrated how sodium chloride influenced the redox reaction between copper sulphate and zinc. The video followed a structured approach, explaining each step in detail. The concept of catalysis was introduced, highlighting its significance in chemical reactions and how catalysts can alter reaction rates without being consumed in the process. Students prepared two redox reactions, one with sodium chloride as a catalyst and one without catalyst, to observe the difference in reaction rates. They presented the experimental setup and characteristics of the reactants, analysing changes in colour and texture in the solution during the reaction to indicate the stages of oxidation and reduction. These observable changes helped students infer the equilibrium state and to analyse how the catalyst affected the reaction process. Finally, students calculated the rate of zinc disappearance in both reactions, allowing them to compare the efficiency of the catalysed reaction with the non-catalysed one, effectively demonstrating how sodium chloride accelerate the process.

This experiment and video as practical illustration of how inorganic catalysts, such as sodium chloride, can significantly improve the efficiency of redox reactions—an important concept in industrial application. For instance, catalysis is crucial in processes like wastewater treatment, where it accelerates the removal of metallic contaminants through oxidation-reduction reactions. This project allowed students to gain a deeper understanding of chemical kinetics and catalysis. Moreover, creating the video enabled them to clearly and effectively communicate complex concepts using a visual medium, strengthening their scientific communication skills and reinforcing their knowledge of chemical kinetics and equilibrium. This example illustrates how producing educational videos can effectively consolidate theoretical knowledge through experimentation and visual communication on platforms like YouTube.

Figure 3 shows the interface of the Tik Tok video repository, where visually engaging videos summarize key topics. This platform further supports the learning process by appealing to diverse learning styles and promoting broader outreach.

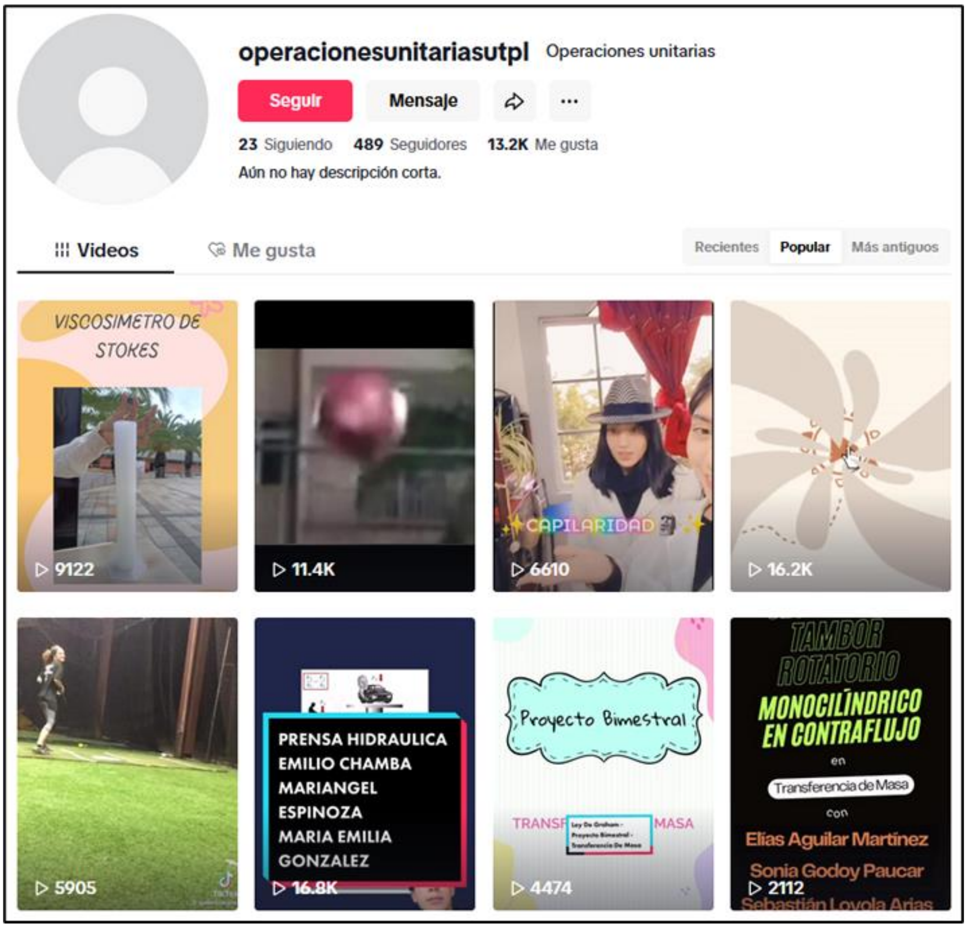

Figure 3. Interface of the Tik Tok video repository (available on: https://www.tiktok.com/@operacionesunitariasutpl)

An example of a TikTok project is the video titled "Urban Polymer Management," which introduces the main types of commercially used polymers, including PET, HDPE, PVC, LDPE, PP, PS, and others. This video provides a concise overview of each polymer's primary applications and addresses the environmental impact caused by plastic accumulation. Students emphasized the importance of proper handling and recycling practices to reduce environmental impact, promoting sustainable solutions for plastic waste. Through engaging visuals and brief explanations, this video effectively communicates essential information about polymer types, their uses, and the necessity for responsible waste management, all presented in an ideal format for social media platforms like TikTok.

3-2- Measurement of Suitability and Reliability of Instructional Materials Motivation Survey

Kline et al. [71] recommend having 2 to 5 responses per item for preparing an exploratory factor analysis (EFA). In this study, a total of 38 items were included in the survey, and a robust sample size of n=2964 responses was collected, providing an elevated item-sample ratio. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Berlett's test of sphericity were employed to assess the appropriateness of the sampling for each variable in the model and for the model as whole. The results of the KMO test are shown in Table 2. For all variables (total instrument), the KMO value was meritorious (0.89), while the dimensions showed marvellous values (between 0.91 and 0.95). Bartlett's test yielded a significant result ($P<0.0001$). According to Kaiser (as cited by Nkansah, 2018), the KMO test produces values ranging from 0 to 1, with values between 0.00 and 0.49 considered unacceptable, 0.50 to 0.59 as miserable, 0.60 to 0.69 as mediocre, 0.70 and 0.79 as average, 0.80 and 0.89 as meritorious, and 0.90 to 1.00 as marvellous. KMO values between 0.8 and 1 indicate adequate sampling, confirming that the data collected in this study were sufficient to analyse student motivation for using PBL and videos in social networks. KMO values below 0.6 indicate inadequate sampling and the need for corrective action. The non-orthogonal rotational factor analysis, using the Direct Oblimin method, identified a single-factor structure comprising all the items on the scale, explaining 67% of the variance. For the four dimensions, the single-factor structure explained between 69% and 79% of the variance. According to Akhtar-Danesh [72], incorporating interactions factors into the model could increase the total explained variance beyond 67%.

For Bartlett's test, the null hypothesis was rejected for both the total instrument and all dimensions (P <0.0001) (Table 2), indicating a strong correlation between variables [73]. Similarly, Nikhil et al. (2023) [73] applied factor analysis to validate a questionnaire for measuring the knowledge, attitudes, and practices motivation, reporting a KMO value of 0.910 and a significant Bartlett's test (P<0.001), confirming the suitability of their data for exploratory factor analysis.

The internal consistency (reliability) of the psychometric instrument, which employs Likert scales, was determined using Cronbach's alpha. The internal consistency of the overall instrument and all dimensions was excellent, with Cronbach's alpha values exceeding 0.90 (Table 2) [74]. According to the literature, Cronbach's Alpha values of 0.70 or higher are acceptable, while values below 0.7 indicate low internal consistency [75]. Previous studies had reported the use of Cronbach's alpha to validate psychometric instrument based on ARCS (Attention-Relevance-Confidence-Satisfaction) dimensions. Laurens-Arredondo (2022) [76] reported a Cronbach's alpha value of 0.89, Guaya et al. reported an acceptable value of 0.7 for the overall instrument [75], and Lijo et al. [77] obtained a Cronbach's alpha equal to 0.906, confirming the reliability of the instrument.

Table 2. Suitability and reliability of instructional materials motivation survey

Dimension	Number of questions	Mean	SD	KMO	Bartlett's sphericity test	Cronbach's alpha
Total instrument	38	3.48	0.73	0.89	<0.0001	0.99
Attention	12	3.47	0.72	0.91	<0.0001	0.96
Confidence	9	3.43	0.74	0.90	<0.0001	0.96
Relevance	10	3.54	0.68	0.95	<0.0001	0.95
Satisfaction	7	3.48	0.78	0.90	<0.0001	0.95

SD: Standard Deviation

3-3- Evaluation of Students Learning Motivation

The IMMS instrument was administered to a total of seventy-eight students. The survey was conducted online, and responses were recorded anonymously. Using a Likert scale, responses to the thirty-eight items were tabulated for each dimension of the ARCS model. Table 3 presents the mean and standard deviation for the total instrument as well as for each dimension. The overall mean was 3.48 ± 0.73, indicating that students had a positive perception of the project, as the mean values fell between "Agree" (scale 3) and "Strongly agree" (scale 4).

Table 3 outlines the results for the twelve questions (QA1-QA12) related to the Attention dimension. Between 88% and 94% of students responded "Agree" (scale 3) or "Strongly agree" (scale 4) to the questions posed. On average, 58% of the students selected "Strongly agree", with the highest percentage attributed to QA1 question: "The audiovisual material captured my attention" and to QA2 question: "The technology for creating audiovisual material attracted my interest".

Table 3. Students' opinions on attention, results expressed as a percentage (%) for each value of the scale

	Attention (%)											
Scale	**QA1**	**QA2**	**QA3**	**QA4**	**QA5**	**QA6**	**QA7**	**QA8**	**QA9**	**QA10**	**QA11**	**QA12**
1	2.6	2.6	3.8	2.6	1.3	2.6	3.8	5.1	2.6	2.6	3.8	1.3
2	3.8	3.8	5.1	6.4	5.1	3.8	5.1	2.6	5.1	5.1	7.7	5.1
3	20.5	32.1	32.1	39.7	38.5	37.2	35.9	33.3	34.6	37.2	33.3	41.0
4	73.1	61.5	59.0	51.3	55.1	56.4	55.1	59.0	57.7	55.1	55.1	52.6

For responses in the lower scales (1= "Strongly disagree" and 2= "Disagree"), questions QA3 (8.9%), QA4 (9%), QA7 (8.9%), and QA11 (11.5%) showed high percentages. These results highlight potential areas for improvement, such as enhancing the quality (QA3) and precision (QA4) of audiovisual materials, promoting curiosity (QA7), and addressing challenges in adapting theoretical content to video format (QA11).

Figure 4 illustrates the mean value for responses to the attention dimension questions. In all cases, the mean value exceeded 3.0, ranging between 3.4 and 3.6. The highest mean values were obtained for QA1 (3.64): "The audiovisual material captured my attention" and QA2 (3.53): "The technology used to create the audiovisual material attracted my interest”. These findings align with Low et al. [51], who emphasized the impact of modern technologies and visually appealing resources in capturing and maintaining students’ attention, particularly in studies involving augmented reality in chemical engineering. Moreover, studies on augmented reality (an audiovisual material) demonstrate that improvement in visual materials help extend student’s attention spans, consistent with the result for QA1. Furthermore, Guaya et al. [75] found that students widely agreed that activities, materials, and organization within PBL initiatives, enhanced by augmented reality, captured their attention. It is worth noting that well-designed audiovisual materials play a key role in stimulating student interest the PBL initiatives [75]. The lowest mean values were recorded for QA4 (3.40): “The material was so precise that it was easy to concentrate on it”, and QA11 (3.40): “The content is easily adaptable to video format”.

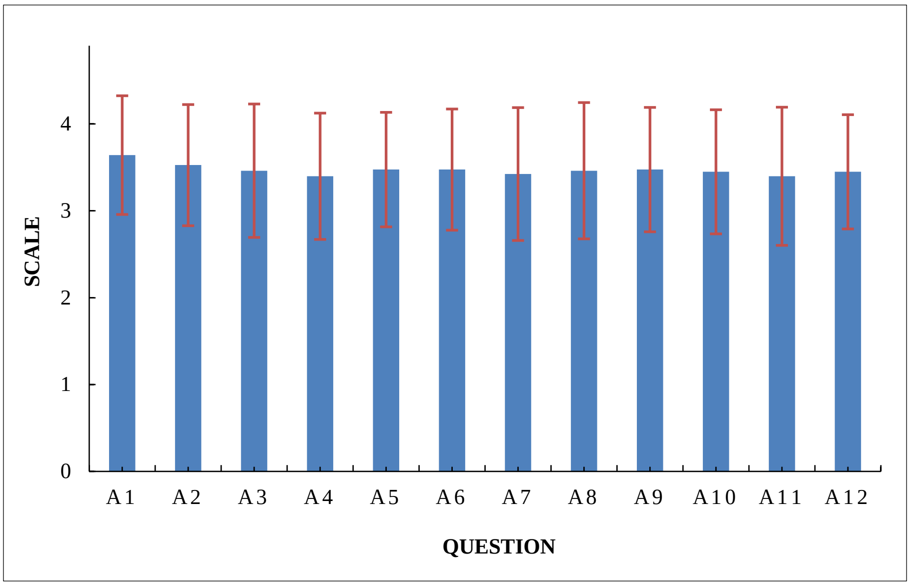

Figure 4. Mean values of students' opinions on attention

Students’ opinions on confidence are shown in Table 4. Responses for this dimension ranged between 88.5% to 96.2% for “Agree” and “Strongly agree”. On average, 54.7% of students selected “Strongly agree”, with QC5 ("While working on this activity, I felt confident that I could learn the content ") receiving the highest percentage, while QC1 had the lowest. QC6 received 60.3% of responses in scale 4, indicating increased confidence in applying theoretical knowledge through audiovisual media. These results are consistent with those reported by Low et al. (2022), where respondents also felt confident learning through augmented reality technology [51]. Smith [78] described higher confidence levels in students creating videos (e.g., for YouTube) compared to writing articles. Moreover, students gained additional educational benefits, such as developing public engagement, enhanced creativity, and presentation skills.

Table 4. Students' opinions on confidence, results expressed as a percentage (%) for each value of the scale

	Confidence (%)								
Scale	**QC1**	**QC2**	**QC3**	**QC4**	**QC5**	**QC6**	**QC7**	**QC8**	**QC9**
1	2.6	2.6	5.1	5.1	3.8	3.8	5.1	1.3	2.6
2	9.0	3.8	5.1	1.3	2.6	2.6	6.4	2.6	5.1
3	43.6	41.0	34.6	35.9	28.2	33.3	38.5	39.7	42.3
4	44.9	52.6	55.1	57.7	65.4	60.3	50.0	56.4	50.0

For questions with responses in scale 1 and 2, QC1, QC3 and QC7 were notable, with percentage exceeding 10%. These lower scores may be linked to initial apprehension when PBL was introduced. QC1(“Upon first viewing the audiovisual material, I had the impression that it would be easy for me to develop”), QC3 (“After receiving instruction, I felt confident about what I needed to apply in this activity), and QC7 (“After working with these types of resources for a while, I felt confident that I could pass a test on the content presented”) reflect areas where students may have initially hesitated. Similar findings were reported by Low et al. [51] were students expressed lower confidence in graded assessment on AR lesson content.

Figure 5 presents the mean values for the nine confidence dimension questions, which ranged from 3.31 (QC1) to 3.55 (QC5). On average, responses leaned towards scale 3 (agree). The confidence dimension responses indicated a positive perception among students, with room for improvement, such as providing more detailed instruction and mentoring to build confidence in successfully completing PBL task and assessments. These results align with findings on confidence levels in AR and PBL [75].

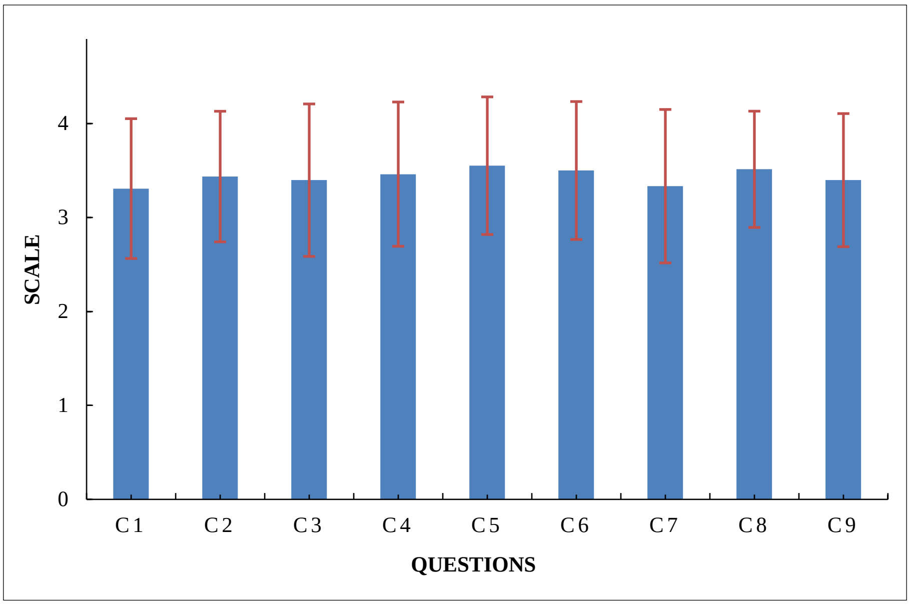

Figure 5. **Mean values of students' opinions on confidence**

Responses to the relevance dimension are shown in Table 5, which includes ten questions. Responses were predominantly concentrated in scales 3 (“Agree”) and 4 (“Strongly agree”), ranging from 91% to 97%. These results indicate a strong positive perception of the relevance of the materials used in the PBL and the creation of audiovisual materials. On average, 62.3% of students responded with “Strongly Agree”, with QR3 ("Successfully completing this project was important to me") receiving the highest percentage (74.4%) while QR1 ("It is clear to me how the content of the audiovisual material relates to things I already know") had the lowest percentage (56.4%). The responses for most questions indicated a good understanding of the project's relevance.

Responses in scales 1 and 2 accounted for 3% to 9% of the total. Notably, QR6 and QR7 each received 3.8% of responses in scale 1. QR6 relates to the relevance of learning and communicating new content, while QR7 pertains to how well the activity addressed students' needs, indicating that a small percentage of students may not have fully connected with these aspects of the project. However, 61.7% of students “strongly agree” with QR6, and 57.7% with QR7. The dispersion of student responses may suggest the necessity of individual support to better highlight the relevance of the activities. These results differ from those reported by Low et al. [51], who found that lesson content was relevant and of high interest to students. In this case, improving the content could further engage and focus students, as reported by Hayes et al. [79], who observed a high percentage (58.6% “agree”) of responses indicating an increased interest in chemistry.

Table 5. **Students' opinions on relevance, results expressed as a percentage (%) for each value of the scale**

	Relevance (%)									
Scale	**QR1**	**QR2**	**QR3**	**QR4**	**QR5**	**QR6**	**QR7**	**QR8**	**QR9**	**QR10**
1	1.3	1.3	2.6	2.6	1.3	3.8	3.8	2.6	2.6	2.6
2	5.1	3.8	0.0	2.6	6.4	1.3	3.8	1.3	1.3	6.4
3	37.2	32.1	23.1	33.3	34.6	33.3	34.6	33.3	33.3	25.6
4	56.4	62.8	74.4	61.5	57.7	61.5	57.7	62.8	62.8	65.4

The mean value for the responses to the relevance questionnaire are shown in Figure 6. The average mean across all ten questions was 3.54, approaching scale 4 (“Strongly agree”). The highest mean value (3.69) was observed for the questions related to the importance of successfully completing the project.

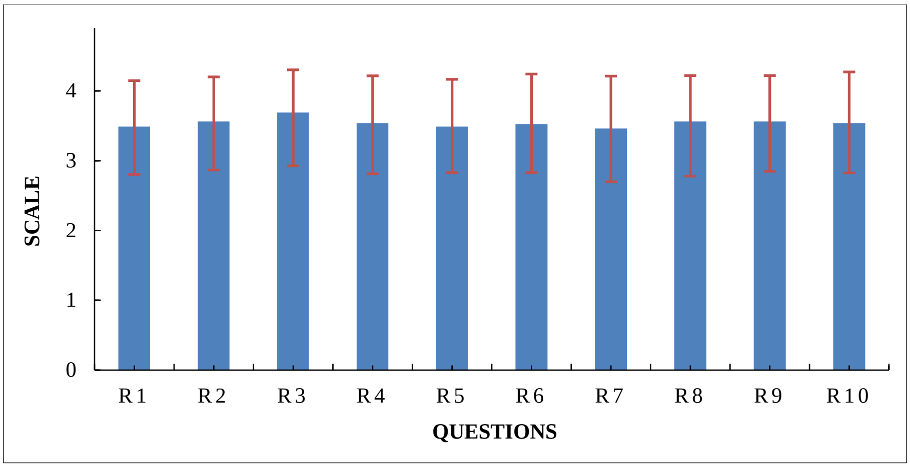

Figure 6. Mean values of students' opinions on satisfaction

Regarding satisfaction, seven questions were posed, and the results of the students' responses are shown in Table 6. On average, 91.4% of students expressed satisfaction with the project, with 61.4% selecting "Strongly agree" (scale 4). Only four students out of 78 (4.6%) indicated total disagreement. The questions with the highest percentage of students in total agreement were QS1 (Completing the exercises in this activity gave me a sense of satisfaction), QS4 (The achievements I reached made me feel rewarded for my effort), and QS7 (I have fun when I create audiovisual material). The results indicate total satisfaction among students when engaging in PBL activities and creating audiovisual materials. Similarly, other studies demonstrate student's satisfaction with the inclusion of audiovisual technology in the PBL tasks [51]. Deng & Yu [80] also explained the high motivation among students due to the adoption of social networking tools such as TikTok in higher education.

Table 6. Students' opinions on satisfaction, results expressed as a percentage (%) for each value of the scale

	Satisfaction (%)						
Scale	**QS1**	**QS2**	**QS3**	**QS4**	**QS5**	**QS6**	**QS7**
1	3.8	3.8	5.1	5.1	3.8	5.1	5.1
2	2.6	2.6	5.1	1.3	2.6	6.4	7.7
3	26.9	33.3	33.3	26.9	37.2	28.2	24.4
4	66.7	60.3	56.4	66.7	56.4	60.3	62.8

Questions QS3, QS6 and QS7 had slightly higher percentages of responses in scales 1 and 2, although these values remained low compared to scales 3 and 4. These questions relate to the enjoyment, pleasure and satisfaction derived from studying and developing PBL projects and related audiovisual materials. To improve satisfaction and motivation responses, suggestions include better project planning, the inclusion of clear guidelines, and immediate feedback. Low et al. (2022) [51] pointed out that satisfaction with PBL activities can enhance intrinsic knowledge reinforcement and promote deeper learning. Additionally, when audiovisual materials are shared on social media platforms, interactions with students and public could help correct and improve communication strategies and motivation, as presented by Benedict & Pence [81] in their study on using of YouTube to teach chemistry.

The average value across the seven satisfaction-related questions was 3.5 (Figure 7). Students reported that they felt a sense of satisfaction when completing the project and enjoyed studying and applying audiovisual resources.

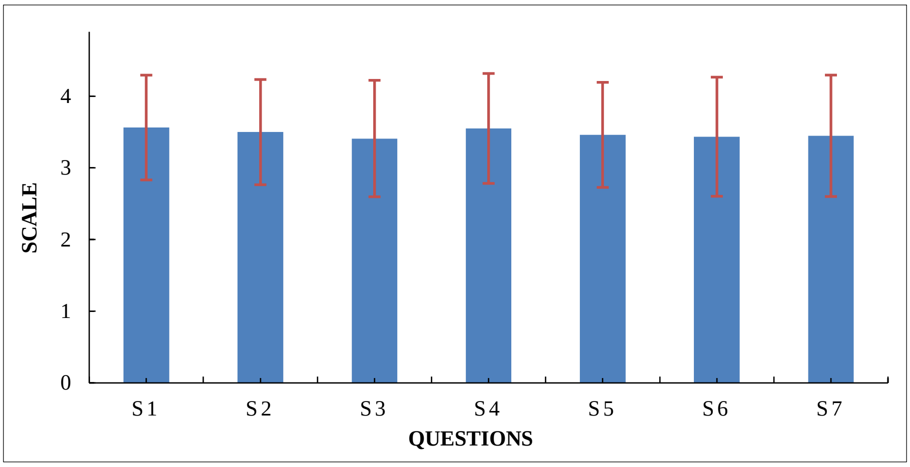

Figure 7. Mean values of students' opinions on satisfaction

Responding to the research questions:

How can PBL combined with social networks enhance the learning experience of chemical engineering students, particularly in the context of unit operations?

The combination of PBL with social networks significantly enhances the learning experience by fostering a dynamic, student-centred environment. Questionnaire results reveal that students exhibited important levels of engagement when interacting with audiovisual content related to unit operations. Additionally, a substantial number of students strongly agreed that the audiovisual materials captured their attention, emphasizing the positive impact of visually appealing resources on the learning process. These findings suggest that integrating social networks encourage more autonomous and personalized learning, enabling students to take control of their education, review content at their own pace, and use social media to collaborate and discuss course material. This integration promotes self-directed learning and enriches peer interaction, making the learning process more interactive and effective. Momin et al. [82] similarly concluded that social media utilization in engineering education enhances student engagement, promotes collaboration, expands access to educational resources, and facilitates communication between students and teachers. Moreover, leveraging social media as a learning environment positively impacts learning outcomes.

Can the combination of project-based learning and video repository facilitate with more interactive and effective learning?

Yes, the combination of PBL and a video repository has been shown to facilitate more interactive and effective learning in unit operations. Students reports finding the audiovisual material highly relevant and expressed high levels of satisfaction upon completing the project activities. The video repository provided students with the opportunity to revisit technical content, enhancing their understanding of complex topics and supporting active and collaborative learning. Although a small percentage of students (3.8%) did not find the content relevant, the majority indicated that the video-based project promoted a meaningful learning and increased engagement. For audiovisual materials to remain effective, continuous updates and proper organization of the video repository are essential. Incorporating the repository as complementary material in a flipped classroom model could further enhance its impact on students learning.

Hayes et al. [79] demonstrated the effectiveness of TikTok and system thinking in facilitating public engagement with scientific concepts and contextualizing chemistry education. Incorporating TikTok to disseminate PBL audiovisual materials could foster interaction by enabling students to participate as content creators or users [83]. Prindle et al. [84] highlighted the use of short-form videos on TikTok and the high level of interaction with students worldwide. Another advantage of TikTok is the ability to share content across other social media platforms. By linking a PBL video repository hosted on YouTube to TikTok, educators could enhance the visibility and accessibility of these learning tools, creating a more comprehensive and engaging educational system. Similar strategies have been proposed by Korich [85], who utilized Instagram, and by Burks et al. [86], who employed Twitter.

Does the use of PBL and social networks contribute with the understanding of unit operations?

The results demonstrate that the combination of PBL and social networks positively contributes to understanding unit operations. Between 91% to 97% of students agreed or strongly agreed that the content and methodology used in PBL were relevant to their learning. Additionally, 60.3% of students expressed confidence in linking theoretical foundations with audiovisual content. Social networks and audiovisual materials enhance understanding by enabling students to revisit content in an interactive and accessible format.

These findings align with Urquiza-Fuentes et al. (2014) [56], who emphasized that video-based learning improves comprehension of threshold concepts, with high levels of student satisfaction. Díaz-Sainz et al. (2021) [87] similarly observed that social networks like YouTube and Instagram positively impact chemical engineering education by increasing student engagement and attention through mobile learning. In line with these findings, Pölloth et al. (2020) [88], emphasized the value of organized video repositories for self-directed learning and as a complementary resource for instructors, particularly in complex subjects such as unit operations. Their work, based on a modular online video library for organic chemistry, supports the use of video as tools to reduce complexity and improve understanding. Valischenko et al. (2020) [89] underscored the pedagogical benefits of creating digital artifacts, such as instructional videos, which increased student motivation and engagement from multiple perspectives: students producing content, peers learning from it, and flipped classroom instructors using it for interactive lessons. Hernáiz-Pérez et al. (2021), [90] reported that students highly rated the use of videos as reinforcement materials in a PBL for CAD laboratories, noting that videos are strategic tools for filling knowledge gaps. Furthermore, Lijo et al. (2024) [62] demonstrated the effectiveness of didactic videos in a STEM YouTube channel. Collectively, these studies highlight the pedagogical value of audiovisual resources and social media in fostering effective, engaging, and student-centred learning environments in chemical engineering.

3-4- Evaluation of Academic Results: Analysis of Average Scores and Feedback

Quantitative analysis revealed average scores across four chemical engineering courses: Mass and energy balance (7.53), Fluid mechanics (7.78), Chemical kinetics (7.77) and Heat transfer (8.49).

These results indicate satisfactory student performance, with the highest average score observed in the Heat Transfer course (8.49). The more technical and theoretical courses, such as Mass and Energy Balance, showed slightly lower averages, suggesting that students encountered greater challenges in those areas.

The results indicate satisfactory student performance as they progressed through the academic cycle, with the highest average score observed in Heat transfer (8.49). The lower averages in more theoretical and introductory courses, such as Mass and energy balance (7.53), suggest that students encountered greater challenges in these areas. Improved performance in advanced courses may reflect increased familiarity with digital tools, enhanced collaboration skills, and deeper engagement with specialized content. Students tended to invest more effort and take on a greater responsibility in project-based activities as they progressed through their studies, recognizing the increasing relevance of the content to their future professional careers.

Prior research suggests that students at higher academic levels often demonstrate a deeper understanding of theoretical concepts and are better equipped to apply them in practical scenarios. In this study, higher engagement levels were observed in more specialized courses, further reinforcing this trend. Additional factors, such as improved group collaboration and cumulative experience with video projects, likely contributed to higher performance in later courses. For instance, students in Heat Transfer demonstrated a stronger ability to integrate complex theoretical principles into their videos, possibly due to their cumulative experience from earlier projects.

The complexity of subjects like Mass and energy balance may have posed greater challenges, which could explain the slightly lower average scores. Courses with a heavier theoretical emphasis often require a more abstract understanding, and students may find it difficult to translate such knowledge into concise and engaging video formats, particularly when using platforms like TikTok. This suggests that additional support may be needed to help students navigate these challenges during the earlier stages of their studies. Nguyen & Diederich [91] highlighted the differences in scientific educational TikTok videos, emphasizing that most are informal and demonstrative, with content types varying across scientific domains.

Overall, the quantitative results suggest that while student performance improves as they progress through their academic activity, a more targeted instructional approach in the earlier courses could further enhance their performance and overall learning outcomes. The positive and negative aspects of this experience are consistent with those reported in previous studies [92, 93] and can be summarized as follows:

Key Insights and Positive Aspects:

- Engagement and creativity: instructors noted high levels of creativity and engagement, particularly in YouTube videos. Students effectively applied theoretical knowledge in creative ways, illustrating complex engineering principles through visual storytelling.
- Development of digital competencies: the use of social media platforms fostered the development of critical 21st-century skills, such as digital literacy, communication, and collaboration. Teachers observed that students adapted well to using YouTube for detailed project explanations and TikTok for more concise, engaging content.
- Improved understanding of practical applications: the PBL approach enhanced students' understanding of the real-world implications of chemical engineering concepts. The hands-on experience of designing projects and creating audiovisual content helped bridge the gap between theory and practice.

Challenges and Negative Aspects:

- Difficulty with concise communication: students struggled to convey complex technical concepts within TikTok 60–90 second time limit for videos. While some videos excelled at summarizing key points, others found it challenging to maintain academic rigor in such brief formats.
- Variability in group work quality: the collaborative nature of the projects led to varying levels of quality across groups. Some exhibited excellent coordination and produced high-quality videos, while others faced challenges in workload distribution and technical presentation.
- Need for more structured guidance: instructors suggested more guidance, particularly for structuring videos for TikTok, could help students refine their communication strategies. Workshops or tutorials on video production and editing could equip students with the necessary technical skills.
- Evaluation of long-term retention of knowledge: future research could explore the use pre- and post-tests, delayed assessments, or follow-up surveys to evaluate the durability of knowledge retention. These tools could also assess how audiovisual resources and PBL methodologies influence students' ability to transfer theoretical knowledge to practical applications beyond the classroom.

Finally, student engagement across the two platforms, YouTube and TikTok, was consistent, with all students (100%) actively participating in both formats. Although no significant differences in engagement levels were observed, the platforms demonstrated complementary strengths in content delivery. YouTube served as a space for in-depth explanations of theoretical concepts, providing a detailed and comprehensive learning experience. In contrast, TikTok encouraged students to convey practical applications in concise and creative ways, making it an engaging tool for succinct presentations. Together, these platforms catered to diverse learning styles and educational goals, demonstrating their potential to enhance the engineering education experience.

While the study did not specifically compare the depth of understanding achieved through long-form YouTube content versus short-form TikTok videos, this presents an intriguing avenue for future research. Such research could analyze how these formats influence learning outcomes, including comprehension, retention, and the ability to apply theoretical knowledge in practical contexts. By exploring these dimensions, educators could gain valuable insights into the unique contributions of each platform and develop strategies to optimize platform-specific content for maximum pedagogical effectiveness. This comparative approach would provide actionable recommendations for leveraging these digital tools in engineering and STEM education.

3-5- Expanding the Applicability of PBL with Social Media to STEM Disciplines

Project-Based Learning (PBL) has consistently demonstrated its effectiveness in enhancing student engagement and understanding across various disciplines. When combined with the dynamic and interactive nature of social media platforms such as YouTube and TikTok, PBL becomes a versatile pedagogical tool, not only for chemical engineering but also for other STEM fields [61]. This constructive interaction allows educators to leverage students' familiarity with digital tools to address discipline-specific challenges while fostering creativity, collaboration, and critical thinking.

The adaptability of this approach lies in its ability to integrate discipline-relevant content into engaging, student-driven projects. By tailoring PBL methodologies and evaluation criteria to the unique needs of different STEM disciplines, educators can create impactful learning experiences that connect theoretical knowledge with practical applications [62]. Evaluation rubrics that include criteria specific to each field's unique competencies are essential. Additionally, providing discipline-relevant guidance, such as using specialized tools or incorporating industry-specific examples, could further enhance learning outcomes. This section explores the potential for extending PBL with social media to STEM disciplines such as biology, physics, and mathematics, and outlines the key modifications necessary to ensure its success. By doing so, this study emphasizes the universal applicability of this innovative approach and its potential to revolutionize STEM education.

4- Conclusion

Integrating social media platforms like YouTube and TikTok into the Project-Based Learning (PBL) framework has significantly enriched the educational experience for chemical engineering students, particularly in unit operations courses. By creating videos to explain complex concepts, students deepened their understanding of theoretical principles while developing essential digital skills such as communication, creativity, and technical proficiency. Quantitative analysis revealed satisfactory performance, with average scores ranging from 7.53 to 8.49, highlighting the effectiveness of this approach in fostering academic success. Teacher feedback emphasized the methodology's ability to promote student engagement and creativity, while also identifying areas for improvement, such as supporting students in conveying technical information more effectively within the concise formats required by TikTok.

The reliability of the study was further validated by a Cronbach's alpha analysis, which confirmed the internal consistency of the survey instrument used to evaluate student motivation and learning outcomes. This robust metric enhances the validity of the findings, ensuring that the data collected accurately reflects the study's objectives. The evaluation rubric, designed to assess content mastery, practical application, creativity, and engagement, proved effective in providing a comprehensive assessment of student performance. To address identified challenges, future iterations of this approach should incorporate targeted support, such as workshops on video production and storytelling techniques, to further enhance students' creative and technical capabilities. This study demonstrates that combining PBL with social media is an innovative pedagogical strategy that bridges the gap between theoretical learning and practical application while equipping students with critical skills for modern professional environments. By leveraging technology and fostering creativity, this approach provides a dynamic and engaging learning experience, aligning with evolving demands of engineering education.

5- Declarations

5-1- Author Contributions

Conceptualization, D.G.; methodology, D.G.; software, E.V.; validation, D.G. and M.M.; formal analysis, E.V. and X.J.; investigation, D.G., M.M., E.V., and X.J.; resources, D.G.; data curation, X.J., E.V., and M.M.; writing—original draft preparation, D.G., M.M., E.V., and X.J.; writing—review and editing, D.G., M.M., E.V., and X.J.; visualization, D.G.; supervision, D.G.; project administration, D.G.; funding acquisition, D.G. All authors have read and agreed to the published version of the manuscript.

5-2- Data Availability Statement

The data presented in this study are available in the article.

5-3- Funding

This research was supported by the Universidad Técnica Particular de Loja.

5-4- Acknowledgments

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5-5- Institutional Review Board Statement

Our study involved undergraduate students as part of a formal academic project aimed at evaluating the educational effectiveness of Project-Based Learning (PBL) enhanced by social media. The project included surveys and instructor interviews, specifically focused on understanding student engagement, academic performance, and motivation, in line with standard pedagogical evaluation methods.

As part of this educational research, no clinical, medical, or invasive procedures were conducted, and no sensitive personal data was collected. All participants provided informed consent to be involved in the study, and their responses were anonymized to maintain confidentiality. Additionally, the study was adhered to ethical guidelines set forth by the Universidad Técnica Particular de Loja to ensure that participants' rights and well-being were protected throughout the research process.

5-6- Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

5-7- Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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Appendix I

Keller's ARCS model of motivation questionnaire applied in the project.

Attention: it is in reference to how students found the project engaging and stimulating.

- The audiovisual material captured my attention.
- The technology used to create the audiovisual material attracted my interest.
- The quality of the audiovisual material helped me stayed focused.
- The material was so precise that it was easy to concentrate on it.
- The images, videos, and texts I encountered during the activity were highly engaging.
- The organization of information using this technology helped me maintain focus.
- The information I discovered throughout the experience stimulated my curiosity.
- The number of activities in developing the audiovisual material was appropriate.
- I learned some surprising or unexpected things from the audiovisual material.
- The variety of audiovisual materials helped keep my attention on the activity.
- The content is easily adaptable to video format.
- Creating audiovisual material keeps me focused.

Confidence: it is about students' perception of their ability to complete projects successfully and apply the theoretical knowledge.

- Upon first viewing the audiovisual material, I had the impression that it would be easy for me to develop.
- This material is as easy to understand as I had expected.
- After receiving instruction, I felt confident about what I needed to apply in this activity.
- The information was sufficient, making it easy to remember key points.
- While working on this activity, I felt confident that I could learn the content.
- It was easy to relate the foundational concepts to the audiovisual content.
- After working with these types of resources for a while, I felt confident that I could pass a test on the content presented.
- I was truly able to understand the material in this activity.
- The clear organization of the material helped me feel confident that I would learn the content.

Relevance: it is in reference to how relevant students found the video projects to their academic and future professional goals.

- It is clear to me how the content of the audiovisual material relates to things I already know.
- The images, videos, and texts proved to be important.
- Successfully completing this project was important to me.
- The content of this material is relevant to my interests.
- There are explanations or examples of how people use the knowledge from these activities.
- The audiovisual material conveys the impression that its content is worth knowing.
- This activity is relevant to my needs.
- I was able to relate the content of this activity to things I had previously learned in class.
- The content of this activity will be useful to me.
- I enjoy reviewing audiovisual material.

Satisfaction: it is an overall level of satisfaction students felt from participating in the video-based PBL initiative.

- Completing the exercises in this activity gave me a sense of satisfaction.
- I enjoyed this activity so much that I would like to learn more about this topic.
- I really liked studying and applying these audiovisual resources.
- The achievements I reached made me feel rewarded for my effort.
- I felt good about successfully completing this activity.
- It was a pleasure to work on this well-designed activity.
- I have fun when I create audiovisual material.