Design and Implementation of Audiovisual Resources to Support the Differential Equations Blended Learning Course

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***Abstract* – The implementation of additional educational resources to support distance learning and enhance blended and virtual instruction frameworks in higher education institutions has become undeniably crucial in the global health crisis. This document details a case study focused on evaluating the impact of audiovisual materials on the academic outcomes of a differential equations course delivered under the blended learning model (b-learning) at a public university in Mexico. These materials, which cover various topics and exercises related to various methods of solving differential equations, are designed to be sequentially integrated into the curriculum and the course schedule, allowing students to access them according to their availability, in alignment with the timetable assigned for online activities. Incorporating digital technologies in distributing and accessing these resources has been essential for designing and monitoring educational activities, facilitating the consultation of additional materials, viewing videos, and completing practical exercises. This strategy has significantly enhanced the learning process, demonstrating the critical importance of integrating digital resources into university pedagogy.**

***Keywords* – Online education, digital technologies, hybrid course, b-learning, differential equations.**

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1. Introduction

Universities play an important role in promoting knowledge dissemination, not only as learning repositories but also as promoters of actions that enhance productivity and improve decision-making. Adamec and Hrmo [1] argue that information and communication technologies are vital in developing these learning skills. Digital technology can be an effective tool for enriching various aspects of the educational process, including the collection and analysis of data, the planning of lessons, and the efficient access to educational materials [2].

Sánchez [3] argues that it is essential for students to acquire a broad perspective of the world, a global understanding, and concurrently, a strong competence in digital learning. The last decade has witnessed how online education has been consolidated as an additional resource of great value for educators, albeit not without challenges. Vivolo [4] notes that, despite its advantages, online education often encounters apprehension and resistance from teachers and students.

The transition from face-to-face courses to online formats entails a process of meticulous planning and design, which requires a significant effort on the part of instructors and familiarization with the digital tools at their disposal [5], [6]. With the outbreak of the COVID-19 pandemic in early 2020 and the subsequent educational emergency, a reorganization towards a virtual education model became imperative, as well as the creation and design of digital educational materials for students and spaces for their online consultation.

Digital technologies assumed a primary role in this context, mediating the teaching and learning processes, and becoming essential components for implementing emergency remote education, as reflected in Figure 1.

This paradigm shift has not only transformed the nature of higher education but has also underscored the importance of adaptability and resilience in the educational field in the face of unprecedented global challenges.

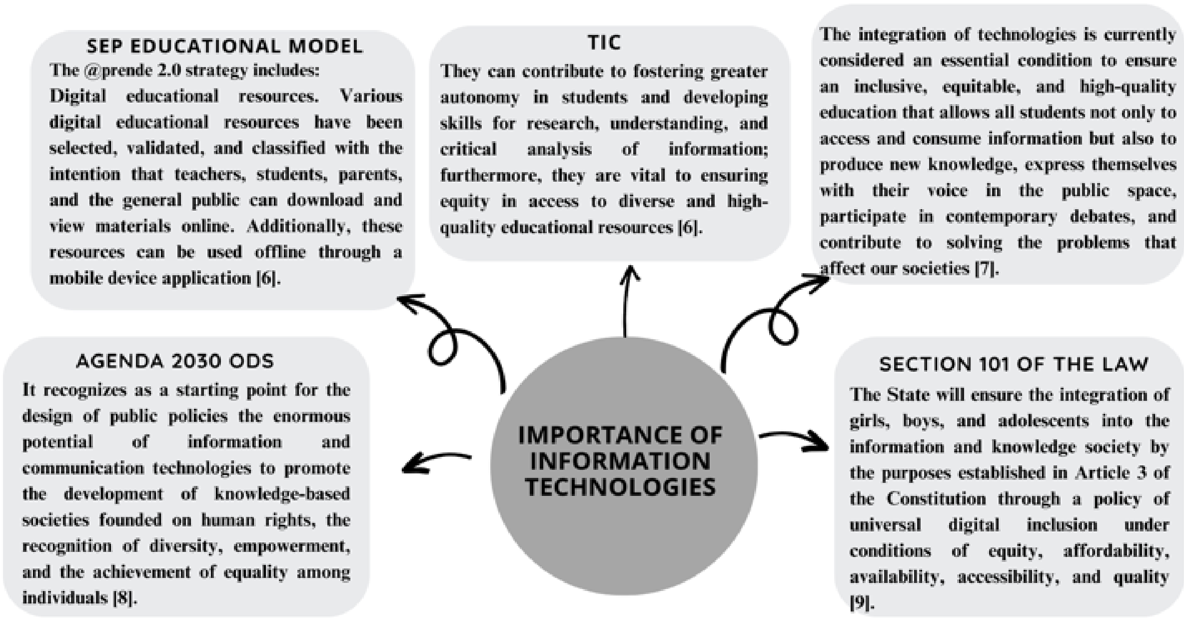

Figure 1. Importance of Information Technologies. SEP (Secretaría de Educación Pública), ODS (Objetivos de Desarrollo Sostenible) y TIC (Information and Communication Technology)

According to the Educational Model of the Universidad Autónoma de Baja California (UABC), within the scheme of the organization of the formative process is the acquisition of competencies that support and enable students to learn how to learn with the objective of developing an integrative vision throughout life. Among these systemic generic competencies are the instrumental ones, such as the "Use of digital tools and information technologies for learning" [10].

With the resumption of face-to-face activities at the beginning of 2022, there has been renewed interest in maximizing the benefits of the previously developed virtual resources, aiming to enrich and expand the students' knowledge base. This situation has significantly encouraged the development of hybrid courses in the field of engineering. The blended learning modality, also known as bimodal, hybrid, or blended-learning (b-learning), seeks to harmonize the inherent advantages of face-to-face education with those of distance learning, and according to Lucena *et al.* [11], its success lies mainly in the human support underlying its implementation. Moreover, this phenomenon has led to a notable increase in the scientific literature related to it, as documented in the study by Borgobello *et al.* [12].

The b-learning methodology, within the context of the contemporary digital society, offers multiple benefits for the field of higher education.

Among these is the possibility of providing students with an extensive volume of information and content that can be easily updated, as pointed out by Cabero and Román [13].

In the field of higher education, one of the most significant challenges faced in recent years has been the integration of virtual platforms within the daily framework of academic environments. Increasingly, university institutions are experiencing an unprecedented fusion between traditional instruction and virtual environments to complement and enrich the educational process.

A consensus has been reached in defining b-learning as a set of pedagogical practices that systematically intertwine direct face-to-face interactions with technologically mediated ones, involving students, teachers, and didactic materials in a continuous and enriching dialogue [14], [15], and [16]. Garrison and Kanuka [17] have emphasized that the academic benefits derived from this methodological combination are palpable and have been recognized since its inception, particularly in promoting learning dynamics that optimize students' educational experience at the higher education level.

Adopting this hybrid modality not only represents an innovative response to the demands of a constantly evolving educational context but also positions itself as a fundamental strategy to promote more interactive, flexible, and accessible learning.

By effectively incorporating virtual environments in university education, a range of possibilities opens up for pedagogical experimentation and curricular adaptation that ultimately contributes to the enrichment of the educational process and the integral development of students. Engineering education is traditionally based on practical, content-centered, and design-oriented teaching, focusing on developing analytical thinking skills [18]. Several tools and methodologies, such as active learning [19], project-based learning [20], and flipped classrooms [21], among others, are available to educators to help improve the effectiveness of their teaching. Studies by Kannadass *et al*. [22] show that computational thinking and mathematical reasoning strengthen students' abilities. However, from the student's perspective, most prefer to learn complex concepts in a classroom environment and believe that online education must facilitate a more deep learning level [23].

In contrast, from the industrial perspective, modern companies need specialists with skills in various theoretical and practical disciplines [24]. Digital technologies are means to achieve human objectives, the integration of digital practices and components, a set of devices used in education and industry: Internet technologies, online learning space, big data, artificial intelligence, cloud computing, and wireless sensors, among others, [26], [27], [28], [29], [30]. The skills that companies require from professionals are leaders who allocate and manage resources properly in their work environment, provide training and form teams under a training scheme based on systematic procedures and techniques [31].

On the other hand, educational videos and educational television have long been implemented in schools at different educational levels for the explanation of complex information [32], [33], [34]. Nowadays, online videos are a strong trend used to popularize science; many are made for educational purposes and uploaded to various platforms for any audience. One of the most prominent platforms is YouTube, which by 2020 claims to have two billion assigned users and one-third of all Internet users [35], [36]. YouTube has become very popular for educational videos and has established itself among students as a complementary learning platform that encourages on-demand learning [37]. In addition, many people use YouTube as a source of information on topics related to science, technology, and medicine [7]. The advantage of online videos lies in their versatility: *"Online video in science has adopted many different styles, formats, and genres, creating a variety of categories that are difficult to classify and have virtually no creative boundaries"* [8].

Therefore, educational videos can be understood as a powerful tool to empower people's knowledge, especially YouTube, with its accessibility and low barriers, which function as a transmitter of scientific knowledge. Moreover, there is an urgent need to develop the willingness and ability to thrive in a digital society where people of diverse nationalities and ethnic groups coexist, each with unique cultural traditions [9].

In the current context, characterized by an accelerated pace of life and the advance of technology, faculty face significant challenges from transitioning from a traditional face-to-face educational model to modalities that require greater adaptability and efficiency in time management. Faced with this situation, several university institutions have adopted innovative strategies, such as the implementation of fully online programs and courses, as well as the adoption of blended learning formats. The latter approach is particularly beneficial to meet the needs of students who combine their studies with work responsibilities, thus allowing greater flexibility and use of educational resources without the limitations imposed by the physical infrastructure of classrooms.

The purpose of this study is to comprehensively examine the aspects related to the delivery of a blended course on differential equations, highlighting the use of didactic videos available on a YouTube channel as a primary educational resource. The research is based on the analysis of statistical data obtained through YouTube analysis tools, focusing on the visualizations and playing time of the videos used in the course. The results offer a detailed view of the impact of the contents and methodologies used on student participation, evidencing the weekly monitoring of the didactic material.

The findings of this study provide a deeper understanding of the factors that contribute to the success of blended learning courses and serve as a reference for developing more effective pedagogical strategies. Based on the results achieved, recommendations are made for teachers to create high-quality and innovative teaching materials, aiming to enrich students' learning experience and optimize educational outcomes in blended learning environments.

2. Methodology

The educational system underwent an abrupt transformation at the onset of the global health crisis, resulting in the mandatory transition from face-to-face and blended learning modalities to digital environments.

This forced adaptation facilitated a detailed analysis of the impact and perception of students belonging to the Facultad de Ingeniería Mexicali (FIM) of the Universidad Autónoma de Baja California (UABC), focusing mainly on their adaptability and performance within the virtual platform. A significant finding of this analysis was the study of the predominant learning styles among the students, revealing that a remarkable 47.1% of the 153 students surveyed preferred a visual learning style. In contrast, the subsequent preferences were distributed among auditory, kinesthetic, and experiential styles. The determination of these learning styles constituted a crucial element for the subsequent creation of personalized didactic resources aimed at satisfying the specific educational needs of the students and, therefore, facilitating the improvement of their learning process. Given this identified need, we proceeded to generate audiovisual content, which not only supported the assimilation and strengthening of the subject matter taught but also contributed to enriching the educational dimension within the digital space.

This study focused on FIM students enrolled in the differential equations course under a blended learning modality. The institution's academic offerings are characterized by its diversity in teaching modalities, including online, blended, and face-to-face options, which are structured in theoretical sessions, workshops, and laboratories, thus adapting to the specific nature of each subject. In the particular case of differential equations, the course was distributed as follows: one hour of the theoretical session and two hours of the face-to-face workshop, complemented by two hours of the virtual workshop. The curricular structure of the course is divided into four thematic units: the first is dedicated to the study of the fundamental principles of differential equations; the second explores solution techniques for first-order equations and their practical applications; the third unit focuses on solution methods for higher order equations and their applications; and the fourth unit covers systems of linear first-order differential equations and their applications.

The implementation of this analysis involved 401 students taking differential equations in the blended mode from the beginning of the pandemic in the 2020-1 school year until the 2023-2 school year. The evaluation of this educational experience not only facilitated the assessment of the effectiveness of the blended model under exceptional conditions but also highlighted the relevance of careful instructional design. Such an approach was essential to ensure the effective delivery of the course, meeting the temporal and methodological requirements necessary to optimize students' academic performance.

Figure 2 illustrates the methodological scheme for teaching the subject, highlighting the importance of a meticulously planned process.

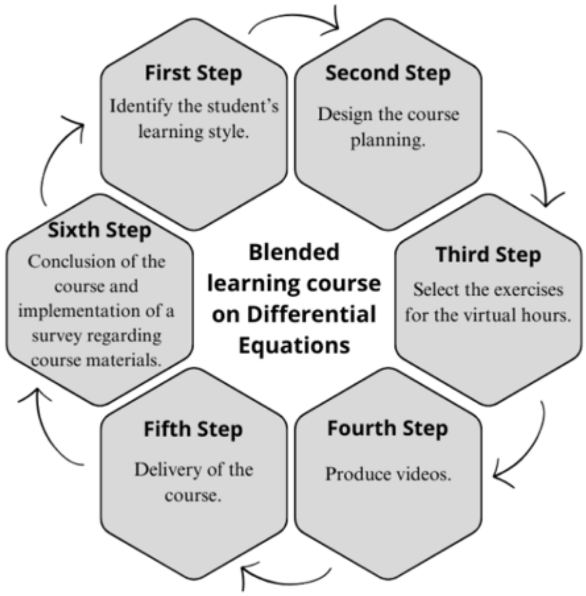

Figure 2. Methodological strategies used for the course of differential equations

This procedure ensures the course is developed efficiently, respecting the established deadlines and adopting the most appropriate didactic strategies.

For the execution of the class, the blended learning or b-learning model was used, employing videos specially developed to complement the two hours of virtual instruction. These audiovisual resources were established to facilitate and enrich the student's education.

2.1. Video Production

In developing audiovisual resources for the differential equations course, an innovative and functional methodology has been adopted that incorporates the use of an iPad together with a virtual blackboard simulation application. This strategy has enabled the production of high-quality didactic content specifically adapted to the academic requirements of the subject.

The exercises selected for presentation in the videos have been meticulously chosen, focusing on those concepts crucial for academic progress within the course. The book a "First Course in Differential Equations with Modeling Applications" was taken as the main reference [25].

As a result of this process, a compilation of 95 videos has been generated and rigorously organized to cover the fundamental topics of the course comprehensively. These materials are classified into three main categories:

- Thirty-six videos exploring the techniques for solving first-order differential equations.
- Thirty-five videos oriented to higher-order differential equations.
- Twenty-four videos focused on applying the Laplace transform.

In order to promote an open access policy and facilitate the dissemination of knowledge, all the videos have been published on the YouTube platform. This measure ensures the availability of resources not only for students enrolled in the course but also for those students from other academic entities interested in deepening the study of differential equations.

2.2. Activities Carried out in Face-to-Face Classes

In the context of face-to-face sessions, the educational process begins with introducing the corresponding topic, as foreseen in the instructional design, assuming that the students have no prior knowledge of the subject. This approach ensures a uniform starting point for all participants, thus facilitating a homogeneous and comprehensive understanding of the material presented. The activities undertaken in this framework focus on the resolution of differential equations by using methodologies suitable for this purpose. Through a systematic didactic strategy, students are guided sequentially through the process, allowing them to effectively assimilate and apply the theoretical principles. It also promotes a favorable environment for students to raise questions or concerns, which have the immediate support of the faculty for clarification. In this way, a fluid learning dynamic is ensured, in which each question and each clarification enriches the academic process and strengthens the assimilation of knowledge.

2.3. Activities Performed in Virtual Classes

During the virtual sessions, detailed instructions are provided to guide students in their continuous learning process. The shared didactic material has been designed to reinforce the concepts and skills acquired during the face-to-face classes. This approach has been highly valued by the students, who express that they find it extremely beneficial, as it allows them to review the content on multiple occasions and reach a satisfactory understanding of the topic in question.

2.4. Platform Used by the Teacher and Students

For the administration and conduction of the course, the Blackboard platform has been selected, distinguished by its capacity as an e-learning tool.

Blackboard enables the execution of videoconferences and the design of structured learning units, contributing to the coherent and systematic organization of the educational content.

Additionally, a complementary tactic that has proven effective has been employed: integrating the Facebook social network. By creating a private group on this platform, a personalized communication link with students is facilitated, improving the attention to queries and doubts arising during their academic activities. This approach optimizes teacher-student interaction and promotes a collaborative and accessible learning environment.

3. Results

The following sections present statistics derived from the video's students viewed as part of the learning process and their perceptions of the blended course approach.

3.1. Video Statistics

The YouTube channel was established and implemented in March 2020, coinciding with the start of the global pandemic. This paper presents a statistical analysis based on data collected from March 2020 through December 2023. In Figure 3, a graphical representation of the playlist's number of views dedicated to the material on differential equations is displayed, highlighting that the maximum peak of views was recorded in November.

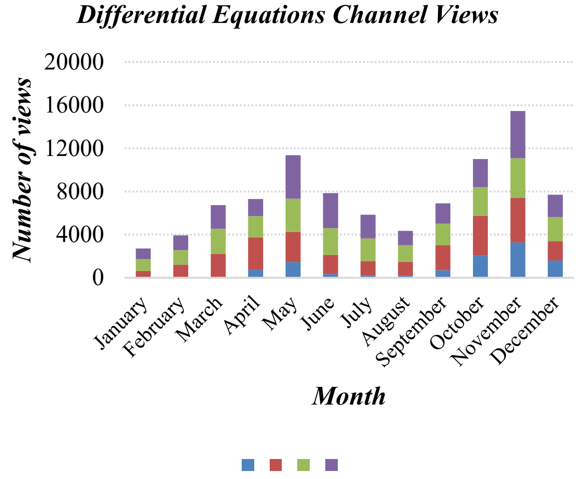

Figure 3. Views on the YouTube channel during the period 2020-2023

Additionally, Figure 4 presents an analysis of the viewing time of the contents related to differential equations. Both graphs show a decreasing trend in the number of views and viewing time during the vacation periods defined by the Autonomous University of Baja California (UABC), specifically during July-August and December-January.

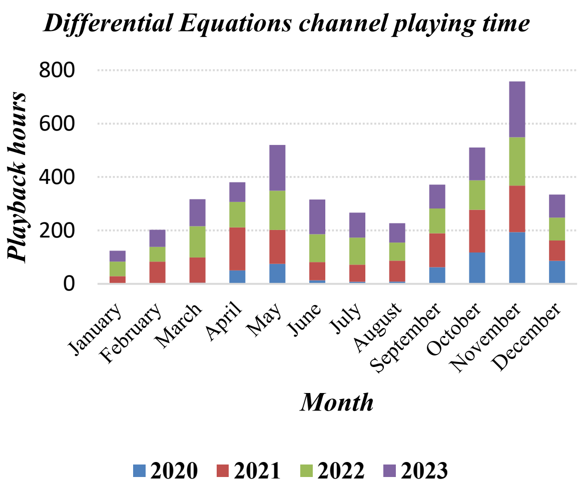

Figure 4. YouTube channel playback time during the period 2020-2023

As a result of the analysis, it was determined that the total volume of views of all the videos corresponding to the differential equations course program amounted to 91,128, accumulating a total of 4,326.11 hours of reproduction. The demographic distribution of the views revealed that 69% corresponded to male users, while the remaining 31% were attributed to female users.

This study provides a detailed view of the viewing behavior of educational content on YouTube, highlighting specific patterns of interaction during the period analyzed. The information obtained is of great relevance for evaluating the impact and effectiveness of digital resources in the learning process, especially in contexts affected by abrupt changes in the educational modality.

3.2. Commissioning Activities Statisticals

In the context of the course taught under the blended learning modality, a structure was established where the face-to-face sessions were scheduled for Mondays, Tuesdays, and Wednesdays. In contrast, the virtual sessions were assigned to Thursdays and Fridays. This analysis focuses exclusively on the 2023-2 school year, taking 40 students as a sample. The data collected indicate that the students complied with the activities assigned by the teaching staff, as required.

The homework assigned to the students was disseminated on Wednesday afternoons, with the instruction to upload their notes as evidence of completing their work during the virtual hours. In addition, it was defined that the deadline for delivering these tasks would be the day before the next face-to-face session. Table 1 shows the number of visualizations recorded during the periods corresponding to the virtual classes.

For example, for the August 10 date, the visualizations were counted from August 9 to 13, in line with the dynamics established for the virtual sessions. The results consistently reflect that several students accessed the audiovisual material multiple times.

Table 1. Planning of topics for virtual class days

Date (2023)	Topic	Views
August		
10	Separable Equations, (3 videos)	219
17	Linear Equations, (3 videos)	216
24	Linear and Nonlinear Models, (3 videos)	253
31	Aplicaciones de Ecuaciones Diferenciales, (3 videos)	214
September		
7	Ecuaciones Exactas, (2 videos)	148
14	Exact Equations and Solutions by Substitutions, (2 videos)	174
21	Homogeneous Linear Equations with Constant Coefficients, (3 videos)	173
28	Undetermined Coefficients: Superposition Approach, (3 videos)	169
October		
5	Undetermined Coefficients: Annihilator Approach, (3 videos)	217
12	Variation of Parameters and Cauchy-Euler Equation, (3 videos)	146
17	Laplace Transform, (3 videos)	171
26	Inverse Transforms and Transforms of Derivatives, (4 videos)	251
November		
3	Laplace Transform: Translation on the s-Axis, (2 videos)	227
9	Laplace Transform: Translation on the t-Axis, (2 videos)	156
16	Systems of Linear Differential Equations and LRC- Circuit, (2 videos)	218

3.3. Statistics of a Survey Applied to Differential Equation Students

A methodological evaluation was conducted by applying a survey to 115 students enrolled in the differential equations course, taught in blended mode from 2022-2 to 2023-2. This survey aimed to determine the students' perception of the course. Of the surveyed population, 87 students participated in the survey.

Figure 5 shows the engineering program to which the students enrolled in the differential equations course belong.

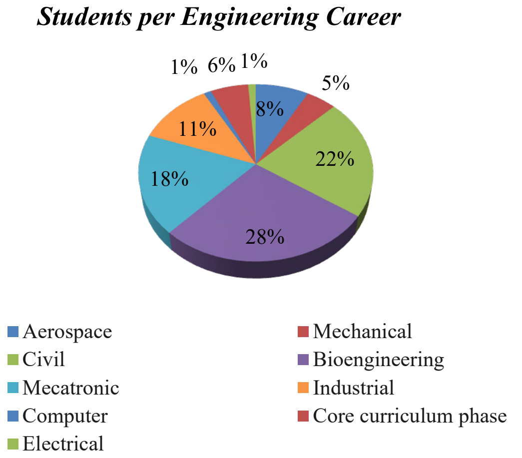

Figure 5. Engineering program of the students who took the differential equations class

One of the crucial aspects of this study was the blended learning modality under which the course is offered, which is of particular interest in identifying the students' preferences about the types of support materials desirable for the virtual sessions. Among the options proposed, 91% of the respondents preferred explanatory videos as the central support resource.

Another question of relevance probed through the survey concerns the feasibility of teaching the course exclusively online, based on the available didactic material. Fifty percent of the students expressed disagreement with this possibility. The reasons for supporting this position included the importance of the exercises carried out in the face-to-face sessions and the ease of resolving doubts directly with the teacher and among classmates. The perception that physical presence in the classroom enriches and complements the learning obtained through online resources was highlighted.

In addition, the need for direct advice from the faculty was emphasized, given the complexity of the topics covered in differential equations. Likewise, although the videos were positively valued for their explanatory clarity, the need to have a physical space where it is possible to work on exercises with immediate assistance was highlighted.

4. Discussion

The established YouTube channel has accumulated 128,395 views, with Mexico leading as the geographic region with the highest number of visits, followed by Peru, Colombia, Ecuador, Chile, and Panama, among others.

It has been identified that the male gender predominates in consuming this type of content, representing 70% of the total number of views. As for the devices users use, 68.6% prefer the computer, 28.3% opt for the cell phone, 1.6% use the tablet, and 0.5% access content through the television.

From the data highlighted in this study, it is noteworthy that almost half of the students, precisely 47.1%, have indicated having a visual learning style. The videos were designed considering the course's subject matter, achieving more than 4,326 hours of playback since their availability to the public. Within the specific demographics of the engineering area, most of the consumers of these videos are men, constituting 69% of the total. An increase in views and playback time is observed during the months of the conclusion of the academic semester, especially in May and November. In addition, 91% of the students expressed a preference for explanatory video-graphic content. Concerning the teaching modality for basic science subjects, 50% of the respondents consider the total online implementation of the course to be viable.

The analysis of the survey data reveals a strong preference for a hybrid educational model, combining both face-to-face and virtual elements, highlighting the significant importance of direct interaction in the educational process and the clarification of doubts. The evidence collected offers valuable insights for planning and improving future editions of the course, underlining the importance of balancing face-to-face and online components to optimize both academic performance and student satisfaction.

This study demonstrates the effectiveness of the blended learning model, emphasizing the need for a meticulous instructional design and the implementation of digital strategies to strengthen the understanding of the curricular material. The availability of audiovisual resources has been confirmed as an essential asset for autonomous learning and constant revision by students, consolidating its value within the modern pedagogical structure.

5. Conclusion

The development of the present study has demonstrated the feasibility of implementing a hybrid teaching model, which integrates face-to-face sessions, in which the teacher can provide direct feedback and resolve student concerns, with virtual sessions with detailed didactic materials that are continuously accessible. Despite the wide range of online resources, the need to classify these contents was identified as a significant limitation, which may hinder students' identification of reliable sources.

Adopting technological tools in the educational process facilitates a more comprehensive learning management aligned with students' individual needs and preferences. This approach promotes a collaborative environment, enhancing the educational experience and contributing to achieving the established academic objectives towards attaining practical and deep learning.

This initiative is oriented towards the modernization and enrichment of the learning process in both face-to-face and virtual modalities but also fosters collaboration and knowledge exchange at a global level within the academic context. The analysis of the differential equations course offered by the School of Engineering Mexicali stands as clear evidence of the adaptability and resilience of the educational sector in the face of unprecedented challenges. Through the effective integration of information and communication technologies and the adaptation of pedagogical strategies to students' learning styles, it has been possible not only to sustain but, in many cases, to improve the quality and effectiveness of teaching in periods of uncertainty.

In conclusion, the study underscores the importance of a hybrid educational strategy as an effective means of enhancing the learning experience and adapting to emerging challenges in the educational environment, thus ensuring continuity and academic excellence in fluctuating contexts.

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