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RESEARCH ARTICLE

REDEFINING LEARNING IN ENGINEERING: THE CHALLENGE-CENTRIC APPROACH

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ABSTRACT

As we approach a new era characterized by swift technological advancements, environmental concerns, and intricate global challenges, it becomes increasingly apparent that conventional approaches to engineering education are no longer sufficient. The well-trodden path of memorizing formulas and equations, while undoubtedly essential, is inadequate in preparing future engineers for the multifaceted issues facing our world. The objective of this study is to redefine the teaching process for engineering students through challenge-based learning and to achieve greater engagement in engineering subject learning. The methodology used was the flipped classroom, to allow students to learn at their own pace and in class, Challenge based learning was implemented, so that with the guidance of the teacher, students could develop their knowledge and skills for the solution of a contextualized problem. The main findings of this study showed a greater willingness of students to learn to use all their skills and knowledge, as students usually seek only to solve an exam and only accredit it. But with this methodology, the qualification was able to increase the approval rate by 30%. In conclusion, the utilization of challenges as a teaching method in an engineering vector calculus class offers significant advantages for students. Challenges provide a practical framework for the application of theoretical concepts and facilitate the development of crucial soft skills.

INTRODUCTION

In the ever-changing sphere of engineering education, one constant remains: the necessity for innovation and adaptation. As we approach a new era characterized by swift technological advancements, environmental concerns, and intricate global challenges, it becomes increasingly apparent that conventional approaches to engineering education are no longer sufficient. The well-trodden path of memorizing formulas and equations, while undoubtedly essential, is inadequate in preparing future engineers for the multifaceted issues facing our world. This realization has given birth to the concept of a "challenge-centered approach" to engineering education, a radical redefinition of how we learn and teach in the field. The central idea is straightforward yet transformative: learning must commence with a challenge. Instead of treating engineering education as a linear progression from theory to application, this approach upends the traditional model. It proposes that students, whether they are aspiring civil engineers designing sustainable infrastructure or robotics enthusiasts creating autonomous machines, should be presented with real-world challenges from the outset.

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The field of engineering has evolved over time, and the demand for engineers with problem-solving skills has increased. It is not enough for engineers to possess theoretical knowledge; they must also have the ability to analyze complex situations, think critically, collaborate across disciplines, and adapt to new and unexpected challenges. This exploration delves into the challenge-centered approach to engineering education, dissecting its core principles and illustrating how it is shaping the future of the field. The pedagogical model empowers students to apply theoretical concepts in a practical context, fostering a deeper understanding and a genuine passion for solving real-world problems. This transformative approach equips students with the skills and mindset necessary to excel in the 21st century and cultivates a new generation of engineers prepared to tackle the pressing challenges of our time. The challenge-centric approach emphasizes the development of technical skills as well as critical thinking, creativity, teamwork, and communication skills. It presents students with real-world problems that engineers face, improving their ability to apply engineering principles in practical contexts. This approach encourages students to think beyond textbook knowledge and prepares them for the complexity of the engineering profession (1).

Challenge-based learning has been found to enhance student engagement, critical thinking, and engineering competencies, according to literature. Research indicates that challenge-based learning results in enduring retention and application of concepts, as it connects education with the actualities of the workforce. Through the resolution of real-world problems, students can gain knowledge on how to generate ideas, prototype, iterate, and ultimately create solutions that are both viable and sustainable (2). Moreover, the approach centered on challenges nurtures an interdisciplinary mentality, urging pupils to cooperate with colleagues from diverse engineering disciplines, and other stakeholders like industry experts and community members. Such collaboration not only augments their problem-solving proficiencies but also acquaints them with diverse viewpoints and alternative solutions, broadening their comprehension of engineering in its entirety. Through practical projects, students also acquire hands-on skills that are arduous to obtain solely via conventional lecture-based learning (3). The implementation of a challenge-centric approach in engineering education presents several challenges. Faculty members may need to modify their teaching methodologies and devise new assessment methods that align with this approach. Additionally, institutions may be required to allocate resources and infrastructure to support practical projects and industry partnerships. Nonetheless, the potential advantages of this approach are significant, as it has been demonstrated to produce engineers who are better equipped to address intricate and interdisciplinary issues in the real world.

MATERIALS AND METHODS

Flipped classroom: Implementing challenge-centric learning in engineering education can be effectively achieved through the use of a flipped classroom approach. In this model, students are tasked with learning the underlying principles and concepts on their own, using online lectures, readings, or other resources. Then, during class time, students are able to put this knowledge into practice by working together or individually to solve real-world engineering challenges (4). Instructors can enhance the learning experience by adopting the flipped classroom model. This approach offers students the freedom to learn at their own speed and concentrate on areas where they require additional assistance (5). Consequently, classroom time is then available for engaging in active learning pursuits like problem-solving, discussions, and collaborative work with peers. These activities are at the core of challenge-centric learning.

Additionally, the implementation of flipped classrooms offers students increased chances for receiving feedback and assessment. Educators have the ability to utilize various resources such as online quizzes, learning analytics, and other tools to track student advancement and offer personalized feedback. Consequently, instructors can pinpoint specific areas where students may require additional guidance and adjust their teaching methods accordingly to enhance student learning (6).

Challenge Based Learning: Challenge-based learning is an educational method that prioritizes the practical application of knowledge to address complex issues or solve real-world problems. Within this approach, students are presented with multifaceted challenges that require a holistic solution (7). These challenges often span multiple disciplines and require students to employ their problem-solving, critical thinking, collaboration, and creativity skills to devise ingenious solutions. Throughout this process, teachers act as mentors, guiding students in the right direction (8). A crucial aspect of challenge-based learning is for students to actively engage with the real world and devise solutions to real problems. This type of learning can take place in a variety of settings, such as classrooms, communities or professional environments (9). Challenge-based learning has found wide application in a variety of contexts, including higher education, in a range of subjects such as science, engineering and technology. In recent years, its potential to cultivate innovative thinking and problem-solving skills in future engineers has garnered attention within engineering education (10).

METHODOLOGY

A learning challenge will be developed in the subject of vector calculus, in the specific topic of curves in space, developing the following steps through the methodology of learning based on challenges:

In preparation for the class, the teacher will provide a collection of videos and reading materials for the students to engage with. This reverse classroom approach involves the teacher conducting research, creating and editing videos that cover the essential concepts and topic development (Figure 1).

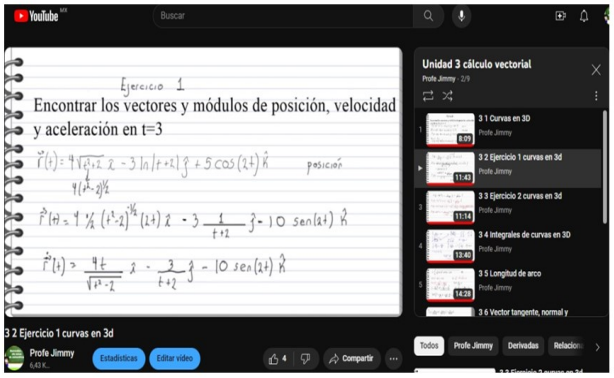

Figure 1. List of flipped classroom videos

During the class, problem-solving will be emphasized, as students apply the theories learned and address any uncertainties that arise from watching the videos. After familiarizing themselves with the fundamental principles of the Flipped Classroom approach in a specialized course, students will engage in a series of practice exercises aimed at resolving any uncertainties that may have arisen during video instruction. Collaboration is emphasized, with students tackling shared challenges and utilizing their cognitive abilities and problem-solving skills to the fullest extent. The methodology's primary objective is to ensure that students go beyond mere comprehension of theoretical concepts and instead grasp their practical applications in real-world scenarios through contextualized exercises.

Then, the teacher's objective is to make a general investigation of problems in the industry that are related to the topics he wants to develop, as well as to find out what skills and knowledge are to be developed with this challenge. Having found the problem, the teacher develops the challenge, providing the necessary data for its development, key questions, as well as a guide to what is desired to be done, as well as developing evaluation criteria, which give signals that the

educational objectives are being met, as well as the teacher develops a basic solution, which can serve as a guide to verify that students do the key procedures and that the problem does not deviate to another situation. In this case, it was a problem statement (Figure 2), in which the students had the objective of proposing a solution to a problem of the design of a roller coaster in an amusement park, not limiting themselves to the solution of the problem itself, but trying to address the different contexts and ramifications that were contemplated, to make a plan for the implementation of the solution.

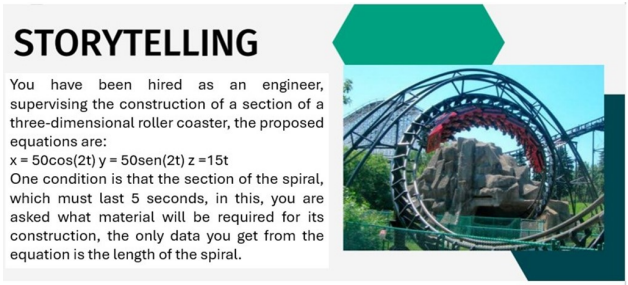

Figure 2. Challenge to solve

They were allowed a period of two weeks, in which, in class, they were confronted with normal exercises of the subject, but which gave clues to the technical development of the solution. In addition, students were encouraged to use their creativity, proposing that they link knowledge from other subjects to the solution of the learning challenge. The objective of this methodology is not only to promote comprehension of fundamental engineering principles, but also to strengthen the notion that engineering is a flexible and evolving process that relies on iterative and creative approaches. This will enable students to recognize that, in their future careers, they will frequently encounter problems that lack pre-established solutions, motivating aspiring engineers to cultivate their capacity to effectively tackle unfamiliar challenges by leveraging all available resources. Finally, the students will develop the presentation in person, in which, in 5 minutes, they will show an executive presentation, which has the purpose of showing how a project is presented to the industry, not limiting it to a technical presentation, but to develop communication and expression skills, capturing the attention of the public to which it is exposed (Figure 3).

Figure 3. Challenge exposition

RESULTS

The main findings of this study showed a greater willingness of students to learn to use all their skills and knowledge, as students usually seek only to solve an exam and only accredit it.

But with this methodology, the qualification was able to increase the approval rate by 30%. In terms of performance, the integration of 5 different subjects was achieved, such as: mechanics of materials, project development, vectorial calculation, accounting and costs: Leadership, teamwork, effective communication, critical thinking, adaptability and time management.

CONCLUSION

In conclusion, the utilization of challenges as a teaching method in an engineering vector calculus class offers significant advantages for students. Challenges provide a practical framework for the application of theoretical concepts and facilitate the development of crucial soft skills. By engaging with mathematical challenges, students enhance their problem-solving and critical thinking abilities, as well as their capacity to work collaboratively in teams, communicate effectively, and manage their time efficiently. This approach also cultivates adaptability and resilience, as students must adjust their problem-solving strategies when confronted with complex issues. The challenge-based approach not only enriches conceptual understanding but also prepares students to tackle real-world situations where practical application of mathematical skills and interdisciplinary collaboration are essential. Furthermore, by experiencing success in overcoming challenges, students build confidence in their abilities, resulting in more meaningful and enduring learning outcomes. Ultimately, teaching through challenges in the vector calculus classroom not only improves students' technical proficiency but also equips them with the necessary skills to confront the complex challenges they will encounter in their future careers in engineering.

GLOSSARY OF ABBREVIATIONS

CBL: Challenge Based Learning

IT: Information Technologies

TECNM Tecnológico Nacional de México

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