Innovative Approaches in Physics Education: Addressing Challenges in Latin America

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Abstract. This symposium highlights research in physics education in Latin America, focusing on technological and collaborative innovations. It features a professional learning community in Chile that uses real astrophysical data, remote laboratories in Costa Rica that facilitate distance education, a critical analysis of pseudoscientific discourses in Brazil, and the use of phenomenography in Mexico to improve conceptual understanding. These initiatives underscore the importance of interdisciplinarity and adaptation to specific contexts, proposing greater technological integration and international collaboration to enhance physics education in the region.

Introduction

Physics education in Latin America encounters unique challenges and opportunities. This region, with its shared history of European colonisation and rich cultural, ethnic, and geographical diversity, continues to struggle with uneven wealth distribution that impedes access to quality education. This symposium gathers research and experiences from various countries across the region, showcasing how interdisciplinary collaboration and the integration of emerging technologies are revolutionising the teaching of physics to address educational needs while acknowledging the specificities of the local context.

Contributions

In Chile, a group of researchers and teachers use real astrophysical data to co-create educational activities aligned with the school curriculum. Cutting-edge science is essential for addressing contemporary challenges, and its integration into education can increase student motivation. However, teachers' limited access to specialised publications and the technical language used hinder knowledge transfer to the classroom. To tackle these challenges, a Professional Learning Community (PLC) has been established where physics teachers, astronomers, and science education researchers engage in dialogue and knowledge exchange. In this case, authentic astrophysical data was used due to its significant importance for the country's scientific development and the interest it generates among students. The activities were implemented with over 200 students aged 14 and 15 as part of formal physics classes, highlighting the importance of interdisciplinarity and teamwork.

In Costa Rica, Remote Laboratories are driving significant changes in distance and hybrid education, allowing students to conduct real experimental activities via the internet. The laboratory equipment is controlled from a graphical user interface, accessible at any time and from any location. This technology removes access barriers, characteristic of the region, democratising experimental activities. The results of using this technology for teaching physics, which became widespread during the COVID-19 pandemic, demonstrate deeper and more meaningful learning outcomes. At the Universidad Estatal a Distancia (UNED), Remote Laboratories have been in use since 2018 and have been offered to various countries in the region.

From Brazil, a critical analysis is presented on the use of quantum physics concepts in pseudoscientific discourses on social media. The growing presence of science communication practices reflects the interest in science in everyday contexts. However, some mistaken views of science can lead to pseudoscientific practices in society, particularly on social media platforms like Facebook and Twitter. The aim was to analyse the relationships between pseudoscientific discourses related to quantum physics and post-truths on Facebook. Specifically, quantum mysticism was explored, understood as an intriguing yet criticisable cultural phenomenon. Critical discourse analysis was adopted as the main theoretical-methodological framework. The results suggest that the descriptions use non-scientific discourses in an attempt to convince the public that the application of quantum physics in everyday life is possible and beneficial. These discursive strategies operate in contexts where appeals to beliefs and desires compete with rational argumentation about the scope of quantum physics.

In Mexico, research on conceptual understanding of various physics topics focuses on phenomenography to explore how students experience and understand these concepts. Physics teachers and researchers in physics education face the challenge of addressing students' learning difficulties. Various research methodologies have been developed, leading to classroom strategies that enhance student learning. Phenomenography is an empirical approach that explores how individuals experience and understand aspects of their environment and the physical world in qualitatively different ways. This analysis defines categories that describe the general ways students experience a research phenomenon. Additionally, multiple-choice assessment tools have been developed to compare different populations and improve teaching strategies based on research data.

Conclusion

The production of knowledge in physics education in Latin America is characterised by its interdisciplinary approach and adaptability to varied contexts. Collaboration between educators and researchers addresses specific regional challenges and develops innovative solutions. This symposium showcases exceptional efforts to tackle some of the main questions in physics education in the region: how to integrate cutting-edge physics into teaching, how to overcome access issues to experimental practices using technology, how to confront pseudoscientific discourses, and how to consider contexts when designing education. These are all key issues to ensure inclusive and quality science education. Future perspectives include greater integration of advanced technologies, strengthening international collaboration networks, and promoting education policies based on research outcomes. This collaborative approach is essential for continuing to improve physics education and preparing new generations to face future scientific and technological challenges.

Professional learning community for teaching physics; using authentic astrophysics data at school

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Abstract. This work presents the characteristics and results of a professional development community implemented in Chile to teach school physics using authentic data from astrophysics research. To this end, we have implemented what we define as the Cutting-Edge Science Education Model at a pilot level, characterised by collaborative work and co-creation between physics teachers and researchers. To determine its effectiveness, an instrument was developed based on a system of pre-existing and emerging criteria. Considering participants' opinions about their experience, this allows us to present the implementation results and suggestions for its widespread use and transfer to other scientific disciplines.

Introduction

Cutting-Edge science is defined as the most advanced and innovative scientific research being conducted in a specific field of knowledge, which is essential for addressing contemporary challenges. Its integration into education can increase student motivation, but presents challenges. On one hand, the scientific community conducts research at a rapid pace and, in the best cases, makes efforts to communicate this knowledge to non-specialized audiences. On the other hand, tools are required for teachers to transform this scientific knowledge into teachable school science knowledge [1]. This dissociation is further exacerbated by teachers' limited access to specialised journals where recent research findings are published, and the technical language used in these publications also hinders the transfer of knowledge to the classroom [2].

To address these challenges, a Professional Learning Community (PLC) has been established [3] where physics teachers, astronomers, and science education researchers engage in dialogue and knowledge exchange to co-construct activities aligned with the school curriculum in Chile. In this particular case, authentic astrophysics data was used because it is a discipline of great importance for the scientific development of the country, and that generates interest in the students [4].

Methodology

The participants of the PLC were invited based on convenience, considering their professional profiles and expertise. The authors of this work were part of the community in the role of participant observers, so they are not considered in this sample. The sample was defined by two physics teachers and two astronomers. In figure 1, the Cutting-Edge Science Education Model development is presented. The model was executed in five major stages, where the expertise of each participant was necessary for its implementation.

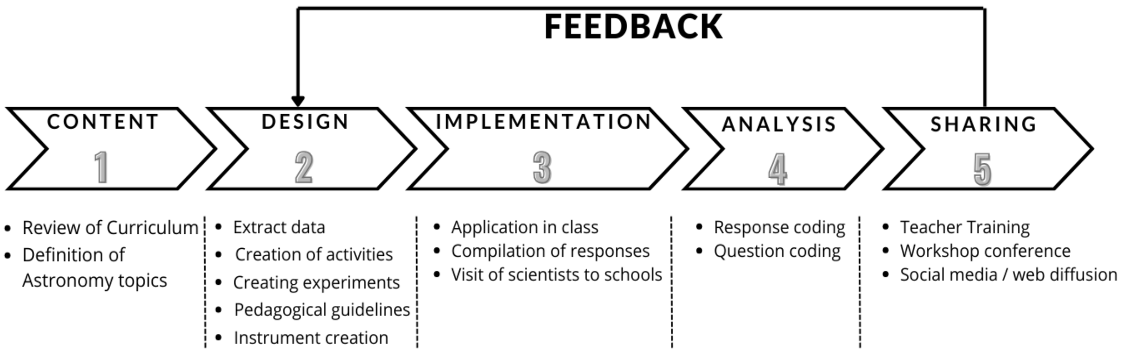

Fig. 1. Stages and activities carried out with the Cutting-Edge Science Education Model proposed. Own elaboration.

A review of the school curriculum was conducted to identify physics topics that could be taught using real data. To develop the activities, data on exoplanets, pulsars and nova light curves were used, available in open access repositories, which are currently used by researchers. The activities have been implemented with more than 200 students aged 14 and 15, as part of formal physics classes.

Findings and Conclusions

Based on the results, we consider that the possibilities and scope of this work are broad. On the one hand, we realise that building bridges between research and the classroom is possible. Doing so implies collaborative work based on horizontality and mutual respect in the training of teachers and scientists. The participants highlight the importance of interdisciplinarity and teamwork to achieve diverse objectives, which has been a satisfactory and constant learning experience for all participants in the learning community. In the case of teachers, the experience has allowed them to critically reflect on their teaching methods and seek innovative approaches to engage students in learning physics. The students' perception suggests that the work carried out using actual data from frontier astrophysics favours the motivation and interest of students in astronomy and scientific work in general.

We note that a limitation of this work is its reliance on technology. In some locations of our country, lack of technology access may hinder data use in the classroom. However, we propose alternatives for its use in the guidelines for teachers that accompany the activities.

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Remote Laboratories: Transforming physics teaching in distance education

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Abstract. This work demonstrates the potential of the UNED Remote Laboratories (RL's) in distance physics teaching, offering practical and interactive experiences to students from all over the world. They are integrated in Moodle, and give remote access to laboratory resources, eliminating geographical barriers and promoting flexibility in learning. Their growing adoption, with peak sessions in 2024 and use in 32 countries, attests to their pedagogical effectiveness. RL's represent an invaluable resource for improving understanding of physics concepts and fostering experimental work at a distance.

Introduction

The rapid advancement of technology is transforming the teaching and learning, placing information and communication technologies (ICT) in the front of educational tools. In particular, distance education has embraced ICT in order to provide flexible and adaptable learning experiences, which are tailored to the unique needs of distance education.

Recently, the concept of conducting laboratory practice via the Internet was unfeasible, however, technological advances have made it possible for RL's to provide authentic laboratory experiences. RL's permit students to engage in hands-on experiments remotely, obviating the necessity for their physical presence in a traditional laboratory [1]. This development has opened up possibilities for integrating RL's into physics education strategies, fostering deeper and more meaningful learning outcomes, which was evident during the COVID-19 pandemic.

Remote Labs

RL's are technological resources that integrate software and hardware to create a real-life experience that can be accessed remotely via the internet. RL's can be classified into two categories: real-time remote laboratories and ultra-concurrent remote laboratories. In a real-time remote laboratory, the manipulation of instruments, observation, and the actual experience occur in a synchronous manner. Such laboratories are limited by the number of students who can utilise them concurrently, and also imply higher maintenance costs. Such laboratories are common in physics education [2]. In an ultra-concurrent laboratory, a set of recordings is made with real equipment and automated by software, configuring an interactive experience for the potential user. These resources represent a powerful alternative for the development of experiences for teaching chemistry and biology, areas in which the development of these resources is limited. UNED Remote Laboratories are managed through LabsLand [3], which allows for high scalability outside the institution.

Methods

At UNED, RL's have been seamlessly integrated into the Moodle learning environment since 2018, utilising the platform's credentials for student access. RL's are employed in both laboratory and theoretical subjects. In the former, they serve as assessment resources for experimental activities conducted in laboratories, while in the latter, they facilitate the completion and subsequent submission of reports by students engaged in experimental activities.

Results

The remote laboratories of the UNED have experienced a sustained and growing use, with the year 2024 being the year that records the highest number of sessions carried out (Figure 1). It is noteworthy that these educational resources have been utilised in 32 countries, thereby demonstrating their efficacy in the teaching of physics.

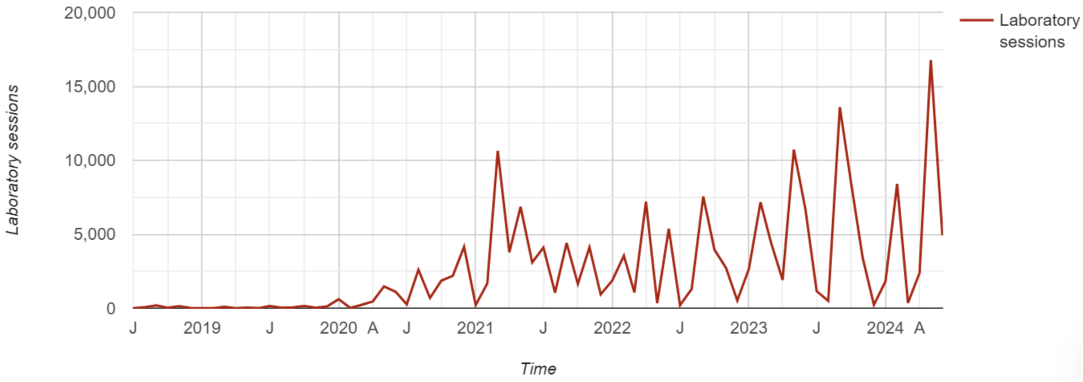

Fig. 1. Remote Labs sessions.

Conclusions

The remote laboratories of UNED have become a valuable educational resource for the mediation of physics, and the continued growth in the use of remote laboratories and the global adoption of this technology is evidence of their pedagogical effectiveness and the commitment of UNED and LabsLand to providing exceptional educational experiences. As technology continues to evolve, remote laboratories are being designed to assume an even more prominent role in the future of global physics education.

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A critical analysis of quantum mysticism in social media discourse

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Abstract. We dialogue with research that investigates aspects of the circulation of discourses related to science in society and its repercussions on understandings, positions and decision-making by non-specialists. Based on critical discourse analysis, our results misuses of Quantum Physics in the context of presenting alternatives to solve everyday problems and/or promote financial, personal, professional, spiritual or health improvements. We have identified a need for investment in new studies that investigate the discursive and rhetorical strategies mobilised by quantum mysticism in an era of post-truths, which can compromise the formulation of public opinion around scientific knowledge.

Introduction

The interest in science in everyday contexts, including popular media, is reflected in the growing presence and importance of science communication practices. However, according to McIntyre [1], some mistaken views of science are formulated due to ignorance of the various contemporary theories developed to describe the development of scientific knowledge and can reverberate in pseudoscientific practices in society, especially on the social media Facebook and Twitter. Based on the assumption that social media are spaces conducive to the existence of discourses of the most diverse nature [2]– be they scientific, pseudo-scientific, anti-scientific, denialist or post-truth – our objective is to analyze relationships between pseudoscientific discourses related to Quantum Physics (QP) and post-truths in the social media Facebook.

Specifically, we explore quantum mysticism, understood as an equally intriguing and criticizable cultural phenomenon, which is present in areas as diverse as politics, arts, medicine and, above all, religion [3].

Theoretical-methodological framework

We have adopted critical discourse analysis as our main theoretical-methodological framework [4]. This involves identifying a social problem and its semiotic representation in analyses that integrate conjunctural and textual aspects. The social problem concerns the impertinence of quantum mysticism related discourses as a basis for individual decision-making in everyday situations. The semiotic representation of this social problem are posts that mobilize QP concepts in texts that suggest their applicability in solving problems outside the scope of the theory, such as personal relationships, professional success, stress and health problems, among others, in social media. Our conjuncture analysis discussed historical, philosophical, social, cultural, discursive and political aspects related to both quantum mysticism and post-truth. This discussion includes (i) the development of Quantum Theory and scientific controversies around it; (ii) the New Age sociocultural movement; (iii) neoliberalism, globalization and the technologization of life. The analysis also involves conceptualizations of post-truth in relation to historical, political and scientific issues, especially those related to scientific denialism and disinformation.

The *corpus* for our textual analyses is a set of descriptions of videos published in Portuguese on Facebook, which are categorised according to their main topic. A subset of exemplar cases was selected for an analysis of intertextual and interdiscursive aspects, through the identification of (i) representations of actors and social events; (ii) epistemic, deontic and appreciative modality markers and (iii) genres and sub-genres, which allude to discursive contexts.

Results and discussion

Results suggest that descriptions use non-scientific discourses in an attempt to convince the population that the application of QP in everyday life is possible and fruitful. This is done through explicit references both to everyday settings (e.g., the workplace) and experiential contexts (e.g., financial hardship). Additional identification and credibility are achieved through naming and portraying individuals who give testimonies about beneficial effects of wearing quantic talismans, attending to courses or engaging in specific healing practices. Such discursive strategies operate in contexts where appeals to beliefs and desires compete with rational argumentation about the scope of QP and its applications. Moreover, they are in tune with an attitude that favors mystical individual solutions to problems which may be grounded on complex sociopolitical contexts (e.g., unemployment, health care).

We identified appeals to beliefs, values and desires of the subjects that characterise a propitious scenario for the construction of post-truths and the use of discursive strategies that articulate cultural, political and historical aspects present in society, strengthening networks of significance and reinforcing ideologies.

Conclusions

We suggest a need for Science Education to problematise a wider range of discourses that potentially form the basis of the making in society. We emphasize, therefore, the necessity for curricular approaches that incorporate dimensions related to discourse analysis that are present in everyday life and that are part of the repertoire that informs students and teachers in decision-making processes in contemporary society.

There is also a need for further research for investment in new studies that investigate the discursive and rhetorical strategies mobilised by quantum mysticism in an era of post-truths, especially in social media, which is the environment in which these discourses are most likely to circulate and be shared, and which can compromise the formulation of public opinion around scientific knowledge.

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Comprehensive Research in Physics Education: From Phenomenography to Multiple-Choice Tools

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Abstract. Physics education researchers confront significant challenges in addressing students' learning difficulties with physics concepts. This manuscript briefly discusses phenomenography, a methodology that emphasizes collective experiences. It explores various studies on students' understanding of crucial physics areas and presents findings from these studies that led to multiple-choice tests.

Introduction

Studies on conceptual understanding are pivotal for generating insights that impact classrooms. In this vein, innovative research methods, including phenomenography, have been developed to assess students' understanding. My research spans topics like vectors, kinematics graphs, mechanics, waves, fluids, electricity, and magnetism. I will overview fundamental research in conceptual understanding, focus on phenomenography, present some results, and discuss constructing multiple-choice tools for comparing different instances or populations within the physics research community.

Research on conceptual understanding

Among other qualitative methodologies, we have used phenomenography [1]. This empirical approach explores how people experience and understand aspects of a phenomenon in qualitatively different ways. It defines categories that describe how learners experience a phenomenon, focusing on collective rather than individual experiences. Phenomenography assumes a limited number of categories that can explain variations in experiencing a phenomenon, making it a practical and relevant tool for research aimed at improving teaching and learning.

Phenomenography has critical characteristics. It collects data on how individuals describe their experiences, with instruments addressing a common theme. The three most used qualitative instruments are interviews, open-ended questionnaires, and student activity reports. Interviews are semi-structured with minimal fixed questions, focusing on how interviewees experience the phenomenon. For instance, interviews may explore students' understanding of wave reflection on a rope. Open-ended questionnaires are crucial to capturing variations in learners' conceptions. The question could be, for instance, about the wave-particle duality. Student activity reports include homework or transcribed video recordings, capturing students' explanations or processes, such as video recordings of group discussions solving a problem.

Review of some conceptual understanding of research findings and multiple-choice tests

We have conducted studies in different fields, all trying to understand how students understand physics concepts. We started some work on students' difficulties with vectors, which led to the Test of Understanding of Vectors (TUV) [2]. Then, we compared students’ understanding of vector in problems with no physical context and three mechanics contexts: force, velocity, and work [3]. In the latter, we found that in the items with the work context that evaluated the interpretation and calculation of the dot product, the work context offers students an extra physical interpretation. Hence, they are more successful in answering those questions.

We worked with first-year students on kinematics graphs on the relationship between position, velocity, and acceleration, which poses difficulties for students. This work successfully modified the Test of Understanding Graphs in Kinematics (TUG-K) [4]. Based on this work, we further continued with the relationship between a variable, the derivative, and the second derivative of the variable in graphical terms, leading to the Test of Understanding Graphs in Calculus (TUG-C) [5]. We found that difficulties are similar, but non-context relationships sometimes pose more problems in understanding the relationships within the graphs.

We explored waves, which led to the modification of the Mechanical Waves Conceptual Survey [6]. In hydrodynamics [7], students applied Bernoulli's equation to different points of the fluid without considering that some were in motion and others at rest. This equation is a conservation law applied to a volume element moving along a streamline or belonging to the same stream pipe.

In electromagnetism, we have worked on the differences in students' understanding of concepts between electricity and magnetism. We have explored the concept of a field and the superposition principle [8], interactions [9], the concepts of electric flux and magnetic circulation [10], and symmetry in electromagnetics laws [11]. Later, we studied students' understanding of the electric field concept through conversions of multiple representations, field lines, vector fields, and algebraic representations [12-13].

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