# New perspective in Physics education research and teaching & learning Physics in Latin-American Countries

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**Abstract.** This symposium addresses four aspects of Physics education research and teaching and learning from Latin American perspective. Research outcomes, experiences and projects that are representative from the diverse lines of work in this multicultural region are presented here. The use of digital technologies, the critical challenges for the social and historical curricular design, the promotion of community participation and some training experiences of in-service teachers are presented and reflected in this work. In this way, this symposium will offer a clear vision of the efforts linked to the research and development of Physics education which are being made in this region of the world.

## Introduction

Latin America is a blend of different cultures; therefore, the development of Physics Education research and the rich experiences on Physics teaching and teachers' training offer an invaluable opportunity to bring to light the significant contributions of this region for the rest of the world.

In this work, a group of researchers of different countries (in alphabetic order): Argentina, Brasil, Costa Rica, Colombia, México and Uruguay, who are part of the MIDEC (Inter-American Table of Dialogue for Science Education- Mesa Interamericana de Diálogo por la Educación Científica) agree to reflect about important aspects of Physics education in order to contribute to wider discussion in an effort for improvement teaching and learning of scientific issues.

## Concerns, problems and advances

The educational community responded to the pandemic by turning to digital technologies. However, there is still a lack of research which explain and guide possible intervention for teaching and learning Science, and particularly Physics in real educational contexts.

In this line, the first work *The experimental activity in Physics education: new digital realities* of Idoyaga, Arguedas Matarrita, Varela and Lorenzo, examines ongoing Physics education research projects in Argentina, Costa Rica, and Uruguay that utilize digital tools.

These projects focus on the use of remote laboratories, taking into account the new model of Extended Laboratory [1] and the research follows the principles of design-based methodology. Through this analysis, emerging trends, areas for further study, and opportunities for international collaboration can be identified.

Teachers are essential to implementing any innovative proposals in Physics Education. Therefore, it is necessary to pay attention on their initial education as well as in-service training and updating. Reflections on curricular design from a social and historical perspective as well as the particular projects centred on in-service training may provide valuable insights for improving Physics education.

In relation to this matter, two articles are included in this symposium. The former, *The Physics teachers' formation and the curriculum reforms in Brazil,* by Mattos and Rodrigues, considers the critical challenges from historical problems in Physics teacher education and current educational reforms for Science education in Brazil. Concerns have been expressed by Science education researchers regarding the rushed reforms and their top-down implementation in the country. The curricular reforms at the high school level have resulted in uncertainty regarding the maintenance of scientific disciplines. Additionally, the shortage of Physics teachers in public schools may lead to the discontinuity or precariousness of Science teaching, potentially contributing to the socioeconomic fragmentation within the professional training of young students.

The latter, *Training of Physics teachers in Colombia*, by Tuay Sigua and Forero analyses the training programs for Physics teachers in Colombia to identify the diverse formation purposes and conditions for their development. The study employs a discursive textual analysis based on program documents and surveys of program directors. The results show that the formation purposes and conditions are not homogeneous and articulated.

All the efforts to enhance Physics education will be in vain if the knowledge obtained does not have an impact on transforming actual communities and contexts. The fourth contribution by Suarez Rodríguez, Teaching Physics and its contribution to the local development,

presents the results of learning experiences that involve community participation and the development of projects that have social and environmental benefits, as well as teacher training, Integrating scientific concepts into real-world engineering and other problems relevant to students' immediate contexts.

## Perspectives to the future

Physics education necessitates the ability to navigate between knowledge and diverse social systems and individuals, including politicians, educational administrators, teachers, students, and others, to transcend existing boundaries. In order to safeguard equity, diversity, and cultural identity, it is crucial to continue research in Physics teaching and learning, not only at the initial stages, but also at higher levels such as university, teacher education, and postgraduate education, to enhance teachers' competencies to meet future demands. Adopting an intercultural perspective, it is essential to increase Physics education research in specific contexts and establish interdisciplinary teams to generate new and innovative proposals for Science Education, as follows:

To foster progress in Physics Education, it is crucial to embrace collaborative efforts that bring together diverse perspectives and areas of expertise. One approach is through interdisciplinary groups that incorporate Physics within the larger STEM framework. Additionally, international groups offer valuable opportunities to share and learn from diverse experiences worldwide. Furthermore, multilevel and mixed groups that involve both Physics teachers and researchers can facilitate constructive discussions on real-world challenges and innovative solutions. With the importance of international cooperation in mind, it is essential to promote open and multidirectional dialogue to shift the focus from "for" to "among all." By doing so, we can work towards a more integrated and equitable world.

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# The experimental activity in Physics education: new digital realities

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**Abstract.** This study presents an analysis of research projects in Physics education that employ digital mediations and are currently being carried out in Argentina, Costa Rica, and Uruguay. The COVID-19 pandemic has accelerated significant changes in educational practices, resulting in the establishment of hybrid modalities. Consequently, these lines of research related to the use of technology in classrooms have become a top priority. The analyzed projects have demonstrated a particular interest in the use of remote laboratories, and the methodology employed adheres to design-based research principles. Such research enables the identification of emerging trends, knowledge gaps, and opportunities for cross-border collaboration.

## Introduction

During the COVID-19 pandemic, educational institutions were compelled to rapidly adopt digital teaching tools in order to ensure pedagogical continuity. This resulted in the incorporation of digital technologies and has led to the emergence of new hybrid or technology-rich educational settings beyond the initial Emergency Remote Teaching phase. However, the field of physics education has faced unique challenges in adapting to this new reality. Experimental activity remains one of the privileged modes of knowledge acquisition in this discipline, and laboratory practices are highly valued for promoting intellectual and sensorimotor learning procedures specific to the field. Despite this, these activities were not fully integrated into the digitalization process, and the incorporation of new technologies has been inconsistent or uncritical.

This paper reports on research conducted in Argentina, Uruguay, and Costa Rica, which examines the role of digital resources in physics education in the post-pandemic educational landscape. The paper presents findings and the general characteristics of several projects that aim to design teaching with experimental activities mediated by technology, thus addressing the challenges faced by physics education during these unprecedented times.

## Theoretical framework

Experimental activities are pedagogically designed actions that involve students in the creation and/or manipulation of devices and instruments to recognize, manipulate, and measure variables. These activities are now considered a complex and highly specialized set of practices specific to scientific education [1], which must be included in teaching proposals from a didactic and epistemological perspective to optimize student learning.

The challenge in designing science education with technology is to redefine experimental activities. The Extended Laboratory (EL) model [2] proposes the systematic use of devices and strategies for experimental activities in digital educational environments. EL includes Simple Experimental Activities, Simulations, Smartphones or Mobile Laboratories, Virtual Laboratories, Remote Laboratories (RLs), and emerging technologies. Furthermore, the EL model consists of general principles for designing science education with technology to increase students' degrees of freedom, diversify and personalize experimental activities, and consider heterogeneity. These principles can also be a valuable input for addressing Design-Based Research.

## Methods and findings

The methodology employed is that of a qualitative and descriptive documentary study. Various research projects, partial and final reports developed between 2020 and 2023, were analyzed. The studied documents are derived from six funded initiatives being carried out at the *Universidad de Buenos Aires* (Argentina), the *Consejo de Formación en Educación* (Uruguay), and the *Univerisdad Estatal a Distancia* (Costa Rica). For the analysis, categories were generated post hoc using the constant comparative method and triangulation of researchers.

The primary findings shed light on several important matters. Firstly, all the analyzed documents (6/6) detailed significant changes in the education system following the pandemic, such as the introduction of hybrid modalities in higher education and the incorporation of technology throughout the system. These documents also highlighted the dearth of technology designed for experimental activities in physics and the importance of teacher training.

Secondly, the incorporation of different types of technology in physics classes was mentioned in most cases (5/6), including simulations, virtual and remote laboratories. Notably, the latter were presented as promising for teaching physics by facilitating real experiences of high sophistication and increasing student autonomy. These projects made it clear that it is essential to propose the synergistic use of various devices. In addition, several of the analyzed documents (4/6) raised concerns about the scarcity of resources and developments adapted to the Latin American context, highlighting the importance of regional cooperation.

Finally, the methodology employed in all the analyzed projects included qualitative and quantitative strategies. Half of the cases (3/6) proposed design-based research as a strategy for generating knowledge, teaching and learning sequences, and rapidly impacting classrooms.

## Conclusions

The work carried out clearly demonstrates the concern of Latin American researchers regarding the teaching of physics in the new educational contexts. Specifically, regarding the need to redesign experimental activities to adapt them to the new reality. It is important to highlight that the studied projects propose the need to carry out experimental activities with different digital mediations. This aligns with the guidelines of the EL. Furthermore, there is a notable trend towards opting for design-based research and international cooperation as a strategy for improving physics teaching. Consequently, it is essential to sustain actions over time to achieve the implementation and analysis cycles inherent to this approach.

As a corollary, it is opportune to add that the systematic study of research projects is of interest, as it allows for the recognition of the main lines of work, the identification of areas of vacancy, and the finding of opportunities for cooperation.

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# The Physics teachers' formation and the curriculum reforms in Brazil

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**Abstract.** We will discuss the historical problems in physics teacher education and current educational reforms that pose critical challenges for science education in Brazil. The science education researchers are concerned about the hurried reforms and top-down implementation imposed upon the country. The curricular reforms at the high school level bring uncertainty regarding maintaining scientific disciplines. Moreover, in public schools, the physics teacher shortage may imply the discontinuity or precariousness of science teaching and, therefore, the expansion of socioeconomic fragmentation within the youngsters' professional training.

## Introduction - The curricular reforms in Brazil

Brazil has lived in recent years in a threatened democratic state whose consequences deeply affected the relationship between teacher training and science curricular reforms. In this period, the same political forces that supported the rise of the right wing in many countries worldwide sustained the rise of anti-scientific propaganda movements. This movement attested to science education's failure in recent years in the face of massive alienation through fundamentalist propaganda of fake news and support for post-truth. Propaganda aiming at discrediting science was spread not just in Brazil but across the world. The student's initial misconceptions or beliefs got even stronger as a backfire effect, and many teachers became unprepared to deal with students' beliefs and idiosyncrasies in the classroom. [1].

Various countries, including Brazil, have made educational changes in recent years [2]. Many educational reforms have specific international interests, explicitly supported by international institutions such as the OECD, the World Bank, the World Trade Organization, and large corporations such as Pearson. It seems that these economic and private institutions supporting educational reforms contribute to the uncritical alignment of the educational systems to the interests of capital [3,4].

After the 2016 coup d'état in Brazil [5], the new government implemented a new political project that impacted the educational system with a speedy reform of the High School system based on a Provisional Measure enacted and transformed into law the same year. During the same rushed process, the Common National Curriculum Base (BNCC) was implemented and approved a year later. It was viscerally associated with the Secondary Education reform, supposedly to create an educational system allowing students to choose their career when entering this level of education. However, this curricular change promotes content emptying through the creation of general areas of knowledge. It has reinforced the disparities between the private and public educational sectors, as the latter had a severe shortage of science teachers, particularly physics teachers.

## The shortage of science teachers

Despite the historical efforts in the last decades, the Physics teacher shortage in Brazil has barely changed. We have discussed elsewhere [6] that less than 25% of Physics teachers have proper qualifications, going to 10% in some states. Such low numbers are only found in Chemistry education. Also, a high teacher attrition rate persists, and public policy fails to retain qualified educators. In the last decades, the number of spots in Physics teacher training programs has roughly doubled across the country, but the number of degrees and qualified teachers within the classrooms did not follow the growing trend.

Although there are scholarship programs for undergrad students in teacher education programs, which injects some hope for mitigating the Physics teacher shortage, the lack of a consistent teaching induction program remains a critical gap in educational policy. In most states, the teachers' placement process in the public sector is arranged for open competition, and the time in a teaching career plays a significant role in the school choice. Experienced teachers go to highly-ranked schools, while novice teachers end up far from city centers in schools with higher needs. Such unbalance shapes the types of teaching experience, demands, and guidance fresh Physics teachers will find.

The most common teacher training programs model across the country is the so-called "3+1", in which the undergrad students should attend three years of traditional scientific education, and the last year they should attend courses dedicated to pedagogical topics. This model has been strongly criticized due to its harsh cut between the scientific and pedagogical instructions because it often leaves Physics teaching issues aside. The teaching practice and experiences within the school are delayed to the program's last year. It results in an uneven distribution of school-based activities and no time to digest the knowledge acquired at school (for instance, planning, teaching strategies, learning assessment, etc. [7].

## Consequences: the lack of Physics in the educational system

While examining the current curriculum reform, it is critical to acknowledge the complexity of the task. Besides its continental dimensions and characteristics, Brazil keeps several disparities and inequalities that cannot be quickly addressed. Additionally, national curriculum reform demands changes in different levels and components, such as teacher education, national textbook program, and national high school assessment system, to mention a few.

As far as we can see, the current educational policies, from curriculum reform to teacher education, are not driven toward addressing the historical issues of physics teaching. The curriculum reform seems to solve chronic problems like the physics teacher shortage by erasing physics classes. The top-down replacement of physics contents by competencies and supposed interdisciplinarity without the proper curriculum design, timing, and infrastructure might impose extra pressure on disciplinary courses like Physics.

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# Training of Physics teachers in Colombia

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**Abstract.** The training of Physics teachers constitutes a field of research, which allows to identify, among others, the conceptions of science that guide teaching, the purposes of learning, the role of research, the implications for the social environment and the meaning of Physics in the 21st century. In this communication, the purposes of the 6 training programs for Physics teachers in Colombia are analysed, in order to contrast the different visions that underlie and propose the type of training a Physics teacher should have to meet the needs of the contexts. The results show diverse formation purposes and conditions for their development that are far from being homogeneous and articulated.

## Introduction

The initial training of physics teachers as a field of research poses several challenges, among which stands out, what skills and competencies teachers must have to face the constant changes in social and cultural dynamics, among them, the decreasing interest of young people in science education. Another challenge, in terms of education for all, according to [1], is how to contribute to training from scientific education to critical citizens who participate in decision-making in a responsible manner and with ethical conditions to face the evident crisis of humanity. It also highlights how to achieve relevance of science education, so that students achieve empowerment, which allows them to forge their own interests to meet their needs and society.

The Ministry of National Education of Colombia [2] states that teacher training processes are a factor that impacts the quality of education and requires conditions to meet the territorial and population conditions of the nation through training in disciplinary, pedagogical, ethical, esthetic, investigative, communicative, personal, social and cultural knowledge.

## Frameworks

The professionalism of teachers is crucial at all levels of the educational system. Teacher training has three essential pillars: 1) the teacher's identity, which involves personal, social, cultural, and professional recognition of their role in training others through deep, updated, and projective knowledge; 2) the dignity of the teacher, which includes policies that place the teacher at a certain level of responsibility and recognizing the teacher's dignity as a life project; and 3) the teaching career, which involves continuous innovation, capacity building, and knowledge with real-world experience to meet the challenges of changing students.

For physics teachers, these pillars do not revolve around the discipline of physics but rather on the formation of the teaching subject. It is important to recognize the teacher's role as a permanent collaborator with the community and society and to have academic, technological, scientific, and social support. By prioritizing the professionalism of teachers, we can improve the quality of education at all levels and ensure that teachers are prepared to face the challenges of educating the next generation.

## Methodology

A qualitative methodology is approached with a method of analysis of institutional discourse. This consists of analyzing the structure of reasoning and the argumentative forms of the discourse of the documents of the 6 degree programs in Physics in universities of Colombia, Table 1. This requires a selection of documents according to the established categories of analysis. Then proceed to apply the technique of content analysis.

Table 1. Bachelor's Degree Programs in Physics in Colombia 2023

| Universities | #semesters | Peridiocity admissions | Location | Number of credits |
|---|---|---|---|---|
| Pedagógica Nacional | 10 | Semestral | Bogotá, D.C. | 160 |
| Antioquia | 10 | Semestral | Medellín | 180 |
| Valle | 10 | Anual | Cali | 163 |
| Sucre | 8 | Anual | Sincelejo | 124 |
| Distrital-Francisco José de Caldas | 10 | Semestral | Bogotá, D.C. | 145 |
| Andes | 8 | Semestral | Bogotá, D.C. | 125 |

Half of the physics education programs in Colombia are located in the capital city, and 83.3% of them are developed by public universities. Four out of six programs explicitly state their training objectives and how they align with their program's mission and vision. These programs prioritize formative and production research in the teaching and learning of physics, as well as understanding diverse contexts of formal and non-formal education. Two of the programs aim to consolidate intellectuals capable of making their practice a field of research. However, one program only focuses on training for basic and secondary education levels. All six programs prioritize ethical training, social equity, the meaning of life, and creativity through research and innovation, highlighting their goal of citizen training. In terms of emphasis, the programs focus on pedagogy, pedagogical practice, discipline, didactics of physics, and teaching of physics. Three programs prioritize interdisciplinary training. Five programs include courses in modern physics, and three programs cover computational methods, revealing their different conceptions of science.

Overall, these programs demonstrate a commitment to enhancing physics education through research, interdisciplinary training, and promoting ethical and social values.

## Conclusions

The training of physics teachers is a field of research, which allows to identify, among others, the conceptions of science that guide teaching, the purposes of learning, the role of research, the implications for the social environment and the meaning of physics in the XXI century.

In terms of disciplinary training, a teacher in physics orients his knowledge of physics to the learning process. This is essential to guide the training not only in the discipline but to guide the process towards the conditions of how physics contributes to understanding the world of physical phenomena and its contribution to the solution of problems in the contexts of young people.

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# Teaching Physics and its contribution to the local development

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**Abstract.** The way of teaching and learning science, mainly Physics, has undergone important transformation over the years, especially with advances in technology and active methodologies. The application of scientific concepts to engineering and other problems of the students' immediate context, promotes comprehension. In this paper we share results of learning experiences linked to community participation and the development of projects with social and natural benefits and teacher training.

## STEM and physics learning in rural contexts

The complexity of the modern world, immersed in products developed by science and technology that are thought to somehow favour the economic development of people, the linear model of development (Bush, 1945), proposed that the greater science and technology, greater wealth and greater social welfare, governments bet in the mid-1920’s on scientific development but there were problems of poverty, environment, health and ethics that forced to rethink the scientific-technological policy of industrialised countries and their relationship with society, which has a strong impact on all aspects, from problems to address in public management, the exercise of economic resources and even in science education.

At the end of the nineties, in the United States of America, it was proposed to increase the number of students of careers in the area of Science, Technology, Engineering and Mathematics (STEM), and above all, with a high academic level, able to develop cutting-edge technology during the exercise of their profession and thus compete with students from other regions of the world (Caprile, Palmen, Sanz & Dente, 2015; Honey, Pearson & Schweingruber, 2014). But subsequently a transformation was made from STEM as a public policy, to STEM teaching approach, since then it has been gradually extended to other countries of the world.

With the idea that STEM education promotes students’ understanding on how the environment is constituted, how it works and how to use that knowledge to solve the problems of the context close to the academic environment and daily life. Therefore, it is expected to improve the quality of education and the living conditions of the inhabitants of the territories, especially in areas of high vulnerability.

The implementation of STEM in diverse academic scenarios, both rural and urban, is of primary importance to identify those practices that can be systematized to favour learning, considering the differences between contexts and respecting the worldview of students in each region of the planet where they were carried out, and especially the local problems that solved and how they can be used for reproducibility in places with similar conditions, or not, but that could be adapted to the characteristics of the teaching centre.

It has been seen that the learning of physics under this teaching approach promotes the appropriation of content and facilitates the understanding of concepts beyond memorization, while solving problems of their context.

### Physics and community problems

Identifying problems and proposing solutions requires training that favours the development of cognitive and research skills, especially when these problems come from a real context. The Academic Coordination of the Autonomous University of San Luis Potosi, located in Tamazunchale, San Luis Potosi, Mexico, has been working for ten years to promote learning about physics under a STEM approach.

The work is done based on a group or locality with a need or problem (learning community), identified in conjunction with the inhabitants. Once the problem is identified, the solution is sought by applying the contents of physics and other areas of knowledge, using design methodologies, such as "design thinking", among others.

The problems addressed have ranged from the design of logistics for monitoring epidemics and other public health problems such as the prevention of road accidents to the generation of power from the river current, from the design phase and manufacture of:

- Irrigation systems,
- Rainwater harvesting systems for storage in the upland areas,
- Machinery for agro-industrial development such as solar-powered vegetable drying and seed roasting ovens, grinders, coffee packers,
- Functional foods,
- Land and underwaters vehicles,
- Cranes for sick people
- Community gardens among others.

In addition to the creation of science outreach workshops for non-expert audiences in formal and non-formal settings.

### Final comments

The proposal to extend the teaching environment to other members of the community seems to be an alternative to approach through non-formal scenarios those who have not had the opportunity to attend school, and especially the link with other social groups, called "learning communities", can become allies to solve local problems and invite development in all its components, social, economic, environmental.

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