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TEACHING PHYSICS IN DE: PEDAGOGICAL AND TECHNOLOGICAL CHALLENGES FOR SUBSTANTIVE LEARNING

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ABSTRACT

In recent decades, Distance Education has been gaining ground in the educational scenario, given its possibilities and relationships with digital communication and information technologies. Given this continuous rise, the teaching of Physics has been incorporated into the curricula of different courses and levels of education, raising reflections on its pedagogical development mediated by digital technologies. Therefore, this article, configured in a bibliographic study of a narrative-qualitative nature, seeks to reflect on the challenges inherent in the teaching of Physics in Distance Education, for the substantive learning of this discipline, considering its nuances and objectives for the formation of critical students, capable of understanding its theoretical foundations, in different everyday situations. For this purpose, works published in the open access portal Periódicos CAPES and IEEE Xplore, between 2014 and 2024, were gathered, using search descriptors, inclusion and exclusion criteria and analysis categories for the selection of the bibliographic body formed. Based on the proposed reflections, it was observed that the teaching of Physics in Distance Education gains significance and applicability in view of the didactic possibilities of digital media, mitigating the abstraction of content and bringing students closer to the teaching and learning process.

Key Words: Teaching Physics. Technology and Teaching. Digital Mediation. Meaningful Learning.

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ENSINO DA FÍSICA NA EAD: DESAFIOS PEDAGÓGICOS E TECNOLÓGICOS PARA O APRENDIZADO SUBSTANTIVO

RESUMO

Nas últimas décadas, o Educação a Distância vem ganhando espaço no cenário educacional, dadas suas possibilidades e relações com as tecnologias digitais de comunicação e informação. Diante desta contínua ascensão, o ensino da Física, vem sendo incorporado aos currículos dos diferentes cursos e níveis de ensino, suscitando reflexões acerca do seu desenvolvimento pedagógico mediado pelas tecnologias digitais. Este artigo, configurado num estudo bibliográfico de natureza narrativa-qualitativa, busca refletir acerca dos desafios inerentes ao ensino da Física na Educação a Distância, para o aprendizado substantivo desta disciplina, considerando suas nuances e objetivos para a formação do estudante crítico, capaz de compreender seus fundamentos teóricos, em diferentes situações do cotidiano. Para isso foram reunidos trabalhos publicados nos portais de acesso livre Periódicos CAPES e IEEE Xplore, entre 2014 e 2024, sendo utilizados descritores de busca, critérios de inclusão, exclusão e categorias de análise para a seleção do corpo bibliográfico formado. A partir das reflexões propostas, observou-se que o ensino da Física na Educação a Distância ganha significação e aplicabilidade diante das possibilidades didáticas dos meios digitais, mitigando a abstração dos conteúdos e aproximando os estudantes do processo de ensino e aprendizagem.

Palavras-Chave: Ensino da Física. Tecnologia e Ensino. Mediação Digital. Aprendizagem efetiva.

ENSEÑANZA DE LA FÍSICA EN EAD: DESAFÍOS PEDAGÓGICOS Y TECNOLÓGICOS PARA EL APRENDIZAJE SUSTANTIVO

RESUMEN

En las últimas décadas, la Educación a Distancia ha ganado terreno en el escenario educativo, dadas sus posibilidades y relaciones con las tecnologías digitales de la comunicación y la información. Ante este continuo auge, la enseñanza de la Física se ha incorporado a los currículos de diferentes cursos y niveles educativos, lo que ha suscitado reflexiones sobre su desarrollo pedagógico mediado por las tecnologías digitales. Por lo tanto, este artículo, configurado en un estudio bibliográfico de naturaleza narrativa-cualitativa, busca reflexionar sobre los desafíos inherentes a la enseñanza de la Física en Educación a Distancia, para el aprendizaje sustantivo de esta disciplina, considerando sus matices y objetivos para la formación de estudiantes críticos, capaces de comprender sus fundamentos

teóricos, en diferentes situaciones cotidianas. Para ello, se recopilaron trabajos publicados en el portal de acceso abierto Periódicos CAPES y IEEE Xplore, entre 2014 y 2024, utilizando descriptores de búsqueda, criterios de inclusión y exclusión, y categorías de análisis para la selección del cuerpo bibliográfico formado. A partir de las reflexiones propuestas, se observó que la enseñanza de la Física en la Educación a Distancia gana significancia y aplicabilidad delante de las posibilidades didácticas de los medios digitales, mitigando la abstracción de contenidos y acercando a los estudiantes al proceso de enseñanza y aprendizaje.

Palabras clave: Enseñanza de la Física. Tecnología y Docencia. Mediación Digital. Aprendizaje Eficaz.

1. INTRODUCTION

Teaching Physics requires a solid command of the concepts and abstractions inherent to the subject matter, as well as pedagogical expertise and fluency on the part of the instructor in terms of the strategic use of teaching resources, linguistic proficiency, and clear mathematical presentation of problems related to the content. Silva, Sales, and Alves (2018, p. 25) express this concern, emphasizing that subject matter expertise is paramount for the teacher, noting that:

> [...] the lack of subject-specific knowledge on the part of the teacher further exacerbates the problem of teaching in schools, reducing the teacher to a mere mechanical transmitter of textbook content—content that is often structured around a sequence of concepts whose progression is not always clearly justified.

Regarding language, Shibasaki and Lima (2018), as cited in Siqueira (2023a, p. 80), acknowledge the positive and mediating elements of language in the communicative act, recognizing them as crucial to the learning process—especially in the context of technology-mediated instruction—arguing that:

> Recognizing that language and communication can take various forms and reach the interlocutor in different ways, current digital information and communication technologies are able to leverage most elements of the linguistic field, promoting greater efficiency in the communication process through the use of interactive audiovisual resources, thereby breaking away from unidirectional, teacher-centered expository practices.

In this regard, each learning environment presents its own challenges and possibilities, forming a complex ecosystem in which teachers and students engage dynamically in the teaching and learning process, with content and language appropriation at the core of this process. The conventional classroom remains the most common and significant learning space, where direct dialogue between teacher and students takes place. This environment allows for the use of specific pedagogical resources, targeted activities, and assessments appropriate to this context, with the teaching of Physics being shaped by this reality.

However, in the context of Distance Education (DE) and its pedagogical possibilities, the teaching of Physics has been redefined within learning environments mediated by digital information and communication technologies. This redefinition aims to develop effective teaching approaches capable of making learning meaningful for students enrolled in this modality, with the student positioned at the center of the process (Hospodar, 2015). Consequently, new educational paradigms have emerged from the current conditions brought about by DE, with Physics being incorporated as a foundational discipline across various undergraduate programs in the fields of Science and Technology. This scenario demands an appropriate appropriation of Physics concepts by students—many of whom face challenges due to the abstract nature of the subject, often accompanied by complex mathematical techniques embedded within a digital ecosystem, which, according to Coradim et al. (2022, p. 82), "affects individuals' understanding of who they are, how they interact, how they learn and teach, and how they conceive of reality."

In support of this perspective, Moreira and Schlemmer (2020, p. 6) state that "technology alone does not change pedagogical practices, and in order to maximize the benefits of technological innovation—especially those related to digital technologies—it is essential to change the way education is conceived." With the advancement of Distance Education and digital technologies, the teaching of Physics in this modality acquires a new dimension, requiring specific instructional approaches, as well as the strategic use of digital technologies combined with teaching methods that enable students to engage critically and actively with Physics concepts. In this context, students are expected to relate physical knowledge to their daily lives or professional fields.

This article, structured as a narrative-qualitative bibliographic study, aims to reflect on the teaching of Physics in Distance Education today, considering the virtual learning environment alongside the teacher and tutor as key actors in this process. It highlights their roles in facilitating the learning of Physics concepts and mathematical elements within the discipline, seeking to answer the following question: How should teachers and tutors in Distance Education act to ensure effective learning of Physics in this teaching modality? To address this question, studies published between 2014 and 2024 were systematically gathered from the CAPES Periodicals Portal and IEEE Xplore, enabling reflections that analyze the issue at hand. This article is divided into six sections, beginning with the motivations, objectives, and central research problem in this introduction.

Section two discusses the methodological process, emphasizing the concept of narrative-qualitative bibliographic research, as well as the search mechanisms and inclusion and exclusion criteria adopted as parameters to refine the bibliographic corpus of the study. Seeking to understand the didactic stance of the Physics teacher in Distance Education, section three highlights the main interventive strategies employed by this professional to facilitate conceptual and mathematical learning in Physics, reinforcing the importance of scientific education in student development. Section four presents the tutor as a professional capable of mediating the learning process in Distance Education, with emphasis on their modern educational prerogatives, particularly in the context of teaching Physics virtually. The pedagogical intersections between digital technologies and Physics instruction are discussed in section five, highlighting their potential for meaningful learning. The main conclusions, based on the reflections and proposals developed throughout the article, are presented

in section six, alongside new research perspectives centered on the teaching of Physics mediated by digital technologies.

2. METHODOLOGICAL APPROACH

Science is characterized by the validation of knowledge through techniques and systematizations that emphasize investigative rationality. For the phenomenological study of a given event, it is necessary to precisely delineate methods and approaches compatible with the defined object of study. Following this perspective, the present research is based on a narrative-qualitative bibliographic study, aiming to reflect on the teaching and learning processes in Physics education within Distance Education, with a focus on meaningful learning. To this end, studies published between 2014 and 2024 were searched on the open-access CAPES Periodicals Portal and IEEE Xplore, using the following search descriptors on CAPES: (1) "Physics Teaching in Distance Education," (2) "Teaching and Physics in Distance Education," (3) "Physics in Distance Education," (4) "Tutoring and Physics in Distance Education," and (5) "Digital Technologies and Physics Teaching in Distance Education," along with their English equivalents for IEEE Xplore. The inclusion criteria are listed and discussed in Table 1.

Table 1 – Inclusion criteria used to refine the bibliographic corpus

Inclusion Criteria	Considerations
Only studies with more than 50% of their bibliographic references composed of articles.	Articles represent an important source of current research findings, enriching the theoretical framework with data and reflections on phenomena under active investigation.
Studies published in scientific journals rated Qualis Capes A1–B3.	The scientific quality of the selected studies is a decisive factor for validating the reflections developed throughout the research.
Articles that can be reproduced.	The reproducibility of the selected studies reinforces the consistency of the results used.
Articles longer than 3 pages.	The number of pages is directly related to the theoretical depth of the selected studies.
Articles directly related to the defined and used search descriptors.	It is important to gather studies consistent with the established search mechanisms.
Articles with substantial theoretical consistency.	Given the bibliographic nature of the research, it is essential that the studies present sufficient theoretical density to generate assertive reflections on the defined research problem.

Articles exclusively in Portuguese or English.	The study focuses on Physics teaching in Distance Education within both Brazilian and international contexts, with particular emphasis on the Brazilian setting.

Source: Authors (2024).

Similarly, the exclusion criteria presented and discussed in Table 2 were established.

Table 2 – Exclusion criteria used to refine the bibliographic corpus

Exclusion Criteria	Considerations
Gray literature	Works not validated by the scientific community and lacking methodological/theoretical rigor.
Articles with methodological flaws or inconsistencies	Research results strongly depend on methodology, which is a fundamental step for scientific consistency.
Duplicate articles for the same search descriptor	The same search result can be obtained multiple times for the same descriptor.
Articles not evaluated by Qualis-CAPES journals or under evaluation	The consistency of scientific research is directly linked to its publication in peer-reviewed scientific journals.
Preprints	Typically preliminary versions undergoing peer review, and not considered formal publications.
Articles with fewer than 20 bibliographic references	The number of references used in research indicates its scope and theoretical density.
Articles from inconclusive research	Research in progress may be published but can undergo changes during execution, resulting in different outcomes and discussions upon completion.

Source: Authors (2024).

By applying the search descriptors, a total of 148 studies were gathered. Considering the aforementioned inclusion and exclusion criteria, 37 studies were selected; after preliminary analysis and subsequent reading, 25 studies were ultimately chosen. Table 3 highlights the compiled studies, describing their research objectives and the analysis categories established for each, as well as primary information.

Table 3 – Analysis of the selected works for the research bibliographic corpus

Title	Author(s)	Year of Publication	Research Objective	Analysis Category	Directory
Teaching and Learning of Physics in High School and Teacher Training.	CARVALHO, Anna Maria Pessoa de; SASSERON, Lúcia Helena.	2018	To investigate the relationships between teacher training and Physics teaching, highlighting their intersections.	Formative aspects of the Physics teacher and didactic performance.	https://www.scielo.br/j/ea/a/KMMfk3s86fdK6p-TrKmcnFBD/
Online Education and Pedagogical and Administrative Changes.	CORADIM, Josimayre Novelli; COSTA, Josebely Martins de Souza; SANTOS, Claudinea Angélica dos; OLIVEIRA, Silvio Tadeu de.	2022	To map the main pedagogical and organizational changes in education mediated by digital technologies.	Evolution of Distance Education (DE) in pedagogical and digital contexts.	https://www.uemanet.uema.br/revista/index.php/ticseadfoco/article/download/604/403/1569
School Psychology and Possibilities in the Psychologist's Role: Some Reflections.	DIAS, Ana Cristina Garcia; PATIAS, Naiana Dapieve; ABAID, Josiane Lieberknecht Wathier.	2014	To understand the role of the psychologist in school praxis, considering their contributions to the teaching and learning process.	Psychology as an auxiliary tool in teaching practice.	https://www.scielo.br/j/pee/a/kFwV6k4ThTqNSNpp6NYmPft/?format=pdf&lang=pt
The Notion of Time and Space in Distance Education: The Decentralization of the Teaching-Learning Process.	HOSPODAR, Paulo José Ramos.	2015	To understand how Distance Education (DE) and its spatiotemporal possibilities determine teaching practices in this modality.	Distance Education and its spatiotemporal disruption as an impacting factor in the teaching process.	http://pepsic.bvsalud.org/scielo.php?script=sci_arttext&pid=S1807-25262015000200005
Computer Self-testing of Students as an Element of Distance Learning Technologies that Increase Interest in the Study of General Physics Course	IVANOV, Dmitry; IVANOVA, Irina.	2018	To assess the benefits of online tests in Distance Education as a means of support and motivation in university General Physics courses.	To identify how tests can benefit the Physics learning process in Distance Education.	https://ieeexplore.ieee.org/document/8581735

Interactive Teaching Resources for Physics Education: Software Support for Remote or Hybrid Teaching.	LEÃO, Marcelo Franco; SILVA, Samara Sales da.	2023	To highlight the positive impacts of digital resources for Physics teaching in remote or hybrid settings, gathering elements for the systematization of these resources.	Potentialities and instrumentalization of digital resources in Physics education.	https://ppg.revistas.uema.br/index.php/PESQUISA_EM_FOCO/article/view/3303
Learning in Distance Education (DE): The Challenge of Training Online Tutors, with Emphasis on Interpersonal Relationships in Virtual Learning Environments (VLE).	MACHADO, Priscila da Silva Rodrigues.	2019	To analyze possible mechanisms of interaction between tutors and learners in Distance Education, emphasizing relational-human phenomena and highlighting their potential to improve tutoring mediation.	Interpersonal relationships and teaching performance for integration in Distance Education.	https://periodicos.unimesvirtual.com.br/index.php/paideia/issue/view/107
Teaching Physics in higher education: use of information and communication technologies and digital resources	MONTSSERRAT, Maria Magdalena; TURRUBIARTES Iram Razziel Contreras; POSADAS, Martin Guerrero; REYES, Jorge Amaro	2020	To analyze the impact generated by the use of digital media in university Physics education, identifying its main benefits, challenges, and possibilities.	What are the immediate pedagogical benefits in the learning of Physics content in light of digital mediation?	https://ieeexplore.ieee.org/document/9375694
Toward a New Concept and Paradigm of Onlife Digital Education.	MOREIRA, José Antônio; SCHLEMMER, Eliane.	2020	To conceive concepts capable of redefining paradigms focused on education mediated by digital technologies, analyzing the 'real' and the 'virtual' in education.	Intersections between the 'real' and 'virtual' in consolidating learning in Distance Education.	https://revistas.ufg.br/revistaufg/article/view/63438
The Importance of Digital Technologies in the Teaching and Learning of Students in the Final Years of Elementary Education.	OLIVEIRA, Adão Alberlice de.	2023	To understand the impacts related to the use of digital technologies in mathematics teaching practices in the final years of elementary education.	Use of digital technologies in Basic Education.	https://rebena.emnuvens.com.br/revista/article/download/81/75

Motivation in the Classroom: What Do Students Say About High School Physics Classes?	OLIVEIRA, Antônio Nunes de; ANDRADE, Paulo Alberto Avelino; SIQUEIRA, Marcos Cirineu Aguiar.	2018	To establish principles and reflect on teaching practice in Physics education, highlighting elements that impact student engagement in classes.	Student motivation in Physics teaching and its relationship with teaching practice.	https://periodicos.ifrs.edu.br/index.php/ScientiaTec/article/download/2717/pdf/11401
Adaptation of Physics Teaching During the Pandemic: Use of the Game "Quantum Bank" for Quantum Physics Education.	OLIVEIRA, Jéssica, Maria Nunes de.	2021	To present the results of a disruptive practice aimed at Physics teaching in emergency remote education.	Positive impacts of teaching based on the use of gamified digital tools.	https://rgt.ifsp.edu.br/ojs/index.php/revista-cactacea/article/download/7/12
The Use of Video as a Teaching Method and Didactic Resource.	PARADELA, Anna Mirella; SANTOS, Bruna Lima; PINTO, Débora Silva; PINESE, Julia Socci.	2020	To demonstrate how video recording can be used as a didactic teaching method.	Video production as a diversified means of teaching.	https://econtents.bc.unicamp.br/inpec/index.php/inovaeduc/article_download/15324/10200/40028
Distance Education and Digital Technologies.	SANTOS, Aline Renée Benigno dos.	2016	To delimit the use and scope of current digital technologies in Distance Education.	How digital tools are presented in Distance Education and what their potentialities are.	https://publicacoes.ifba.edu.br/etc/article/view/12.
Digital Technologies Applied to Physics Teaching: Didactic Sequence Mediated by Modellus Software.	SILVA, Jade Souza da; ALENCAR, Fábio Pessoa; SILVA, Kariny de Cássia Ramos da; SANTOS, Antonio Marques dos.	2023	To investigate the use of a didactic sequence centered on the application of Modellus software as a teaching instrument.	Use of digital resources to consolidate learning through traditional classes.	https://periodicos.uem.br/ojs/index.php/revisvitruscogitationes/article/download/70793/751375157029/
Didactics in Physics: An Analysis of Its Epistemological, Cognitive, and Methodological Elements.	SILVA, João Batista da; SALES, Gilvandenys Leite; ALVES, Francisco Regis Vieira.	2018	To delineate the basic aspects inherent to Physics teaching, highlighting its didactic processes, teaching paradigms, and the most well-known methods in a reflective manner.	Physics teaching and its fundamental paradigms.	https://periodicos.ufsc.br/index.php/fisica/article/view/2175-7941.2018v35n1p20

Gamification as an Active Learning Strategy in Physics Education.	SILVA, João Batista da; SALES, Gilvandenys Leite; CASTRO, Juscileide Braga de.	2019	To present the possibilities of gamification in Physics teaching, emphasizing its methods and pedagogical relationships.	Impacts of gamified teaching in Physics for meaningful learning.	https://www.scielo.br/j/rbef/a/Tx3KQcf5G9PvcgQB4vswPbq/
Teaching Practice in Physical Education within the Virtual Learning Environment "Canal Educação."	SILVA, Micaelle Cristine Melo da; COSTA, Fábio Soares da.	2023	To map the methods used in Physical Education teaching in Distance Education, presenting generalizations and particularities for its effectiveness.	How is the teaching practice of Physical Education conducted in the Virtual Learning Environment (VLE)? What relationships exist between it and other disciplines?	https://revistas.uece.br/index.php/ensino-emperspectivas/article/view/10491
Physics Teaching Using Virtual Simulators: Potential for Classroom Use.	LOPES, José Soares; SILVA, Aline Gomes da Silva; DE SOUZA, Gustavo Fontoura de Souza.	2023	To analyze the use of online simulators for Physics teaching in the classroom, highlighting their potentialities and pedagogical characteristics.	The use of online simulators in Physics teaching and their benefits.	https://www2.ifrn.edu.br/ojs/index.php/HOLOS/article/view/14365
Language and Digital Technologies in Physics Teaching as Facilitating Elements of Learning.	SIQUEIRA, Kleber Saldanha de.	2023	To investigate how Physics teaching is impacted by the language inherent to digital teaching technologies.	Relationships between language, technology, and Physics teaching.	https://www.fatecpg.edu.br/revista/index.php/ps/article/view/297
The Triad of Language, Cognition, and Emotion as Elements That Enhance Learning.	SIQUEIRA, Kleber Saldanha de.	2023	To understand how language, emotion, and cognition act in the learning process.	IImpacts on the teaching and learning process from the perspective of language, cognition, and emotion.	https://diversitasjournal.com.br/diversitas_journal/article/view/2709
Digital Literacy in High School as an Exercise in Citizenship and Social Inclusion.	SIQUEIRA, Kleber Saldanha de.	2023	To map the main contributions of digital literacy to the civic formation of basic education graduates.	Possibilities of digital literacy in critical-civic education formation.	https://diversitasjournal.com.br/diversitas_journal/article/view/2641

The Role of the Tutor in Consolidating Learning in Distance Education: Reflections on Practice.	SIQUEIRA, Kleber Saldanha de.	2024	To evaluate the functional role of the tutor in contemporary Distance Education, outlining their characteristics and performance.	Tutor prerogatives regarding mediation in contemporary Distance Education.	https://seer.abed.net.br/RBAAD/article/view/702
Learning Situations Applied as Diagnostic Assessments in Self-Instructional Courses at UNA-SUS/UFMA.	SOUSA, Helen Maysa Belfort; TRINDADE, Karoline Corrêa; OLIVEIRA, Ana Emilia Figueiredo de; MESQUITA, Mizraim Nunes; GARCIA, Paola Trindade.	2022	To investigate the importance of diagnostic assessments in Distance Education courses, analyzing the self-instructional scenario and its pedagogical relations.	Importance of the diagnostic evaluation process in Distance Education for the consolidation of learning.	http://www.periodicos.ufc.br/resdite/article/view/72280
Assessment in Distance Education: Conceptions and Possibilities.	SOUZA, Tito Eugênio Santos; MENEZES, Afonso Henrique Novaes.	2014	To define how assessment in Distance Education supports the teaching and learning process mediated by digital technologies.	Systemic evaluation of learning as an active teaching process..	https://www.periodicos.univasf.edu.br/index.php/revasf/article/download/275/170/774

Source: Authors (2024).

3. DIDACTIC PERFORMANCE OF THE PHYSICS TEACHER IN DISTANCE EDUCATION

Initially, we emphasize the importance of the teacher's adequate mastery of Physics content as a fundamental element for establishing effective teaching practices. For Carvalho and Sasseron (2018, p. 52), this reflects an important premise, since "as teachers and educators, we must be consistent." Following this condition, we highlight the significance of the appropriate use of language in teaching practice, enabling the efficiency of communicative processes inherent to educational practice. Considering that each learning environment demands a specific pedagogical conduct from the teacher, the Virtual Learning Environment (VLE), similarly to the conventional classroom, requires the teacher's full mastery of the Physics content to be discussed, alongside adaptation to the virtual teaching environment and its language, as well as "constant mutation, organizational, curricular, extracurricular, and other changes" (Rosa, 2023, p. 2016, apud Silva & Costa, 2023, p. 2). When discussing language, it is important to highlight that it encompasses different forms, scopes, and characteristics, with visual and verbal languages being predominant in teaching mediated by digital technologies.

According to Siqueira (2023b, p. 2750), "language has become part of the new information and communication technologies, encompassing an almost unlimited universe of possibilities, redefining the way we interact, learn, and understand the world." Thus, Distance Education and its pedagogical processes are inextricably linked to the linguistic potentials of audiovisual and textual resources, making it essential for the Physics teacher to strategically know and explore multimedia tools, thereby facilitating the development of physics concepts in a context where autonomous learning is encouraged. From this perspective, both the teacher's mastery of content and the use of digital resources in teaching (videos, online simulations, hypermedia elements, etc.) interact in a balanced manner, leading to the completeness of the teaching process.

It is important to highlight that the use of the digital resources listed in the previous paragraph aims to mitigate the abstraction of the content, without replacing the teacher's protagonism and dialogic interaction within the Virtual Learning Environment (VLE). This interaction is consolidated through the use of forums, chats, video lectures, and other synchronous and asynchronous tools employed by the teacher, whose objective is to bring teachers and students closer together. According to Leão and Silva (2023, p. 141), these compose "what we today know as digital information and communication technologies (DICTs), thus assuming a necessary role within the educational system so that teachers can deliver quality instruction."

At the same time, teacher agility and didactic skills cannot replace digital tools and their linguistic potentialities, since Distance Education (DE) requires the systematic use of technological resources, interactivity, and a proactive student attitude, with the teacher's didactic presentation taking place at appropriate moments (videos, video lectures, and virtual meetings). Furthermore, it is important for the Physics teacher to identify the main conceptual difficulties inherent to each content, adapting the various digital resources explored in the Virtual Learning Environment (VLE) to their instructional objectives.

Consolidating these possibilities, the assessment process in Distance Education should reinforce conceptual learning, motivating student progression while simultaneously revealing to the student their own learning trajectory, strengthening positive attitudes and alerting to possible gaps or failures throughout the process. This aligns with Souza and Menezes (2014, p. 159), who emphasize that "reflecting on assessment has become one of the most pertinent aspects related to teaching practice today, whether in face-to-face, blended, or fully distance education."

Thus, the Physics teacher can select different assessment resources aimed at mapping student performance, allowing for the analysis of their teaching methods, the effectiveness of the digital resources employed, and the assessment methods themselves, which must meet the specificities of the student audience. Aligning with this perspective, Ivanov and Ivana (2018) discuss the importance of assessment methods in Distance Education to stimulate and build student resilience, highlighting, for example, online tests as a means capable of motivating students in this process. These authors, during research conducted with students from the basic cycle of the Moscow Institute of Energy Engineering, found that "to increase students' motivation regarding online tests, the thematic sections of the applied tests should include questions that were repeatedly discussed in face-to-face meetings" (Ivanov & Ivana, 2018, p. 4). This demonstrates the necessary articulation between the

assessment instrument used and its didactic intentionality.

For this, careful planning and appropriate use of digital resources are necessary, allowing for the configuration of a predictable scenario of teaching actions as well as anticipating initial results of the teaching and learning process. In addition to content mastery, linguistic appropriation, strategic use of digital resources, and appropriate use of assessment instruments, the Physics teacher must structure their teaching work in a planned manner, considering pedagogical possibilities and challenges to be overcome.

Within this planning, it is important for the teacher to preliminarily delineate the students' foundational knowledge necessary for the development of a given content, by administering a pre-test that covers fundamental concepts and mathematical operations essential for the upcoming study. To this end, the teacher can design a brief test composed of quick questions with two possible answers — true or false — especially when aiming to gauge the students' level of conceptual understanding of a particular topic or to assess their skills in solving small algebraic problems.

Each content area, given its specificities and the teacher's instructional objectives, may require different types of pre-tests. Furthermore, it is crucial that the teacher establishes a teaching methodology aligned with their goals and the characteristics of the Virtual Learning Environment (VLE), fostering active student participation in the learning context. This aligns with the perspective of Silva et al. (2023, p. 26), who assert that it is "necessary for the teacher to employ methods that challenge students to participate in the class in a practical manner, encouraging increasing engagement."

In Distance Education (DE), various methodologies can be employed to foster student protagonism, particularly through collaborative resources and activities that promote collective engagement. These are allied with the teacher's instructional practice, which may include virtual seminars, the exploration of flipped classroom approaches, and other student-centered methodologies. Thus, for effective Physics learning in DE, it is necessary to integrate a set of interconnected elements that enhance teaching practice within the virtual environment. Planning, content mastery, and the strategic appropriation of digital resources and their languages are key factors impacting this process.

4. TUTORING AND MEDIATION IN THE TEACHING OF PHYSICS IN DISTANCE EDUCATION (DE)

According to Siqueira (2024), the presence of the tutor mediating the teaching and learning process is fundamental for implementing appropriate intervention actions that enable student success in the virtual learning environment. Given that Physics is a discipline often burdened by stigmas and notorious labels such as being difficult, uninteresting, and heavily focused on mathematization, developing a tutoring approach capable of mitigating this scenario represents an important step toward the proper understanding of its theoretical foundations, applications, and materialization, allowing students to identify its principles in everyday life (Oliveira, 2021).

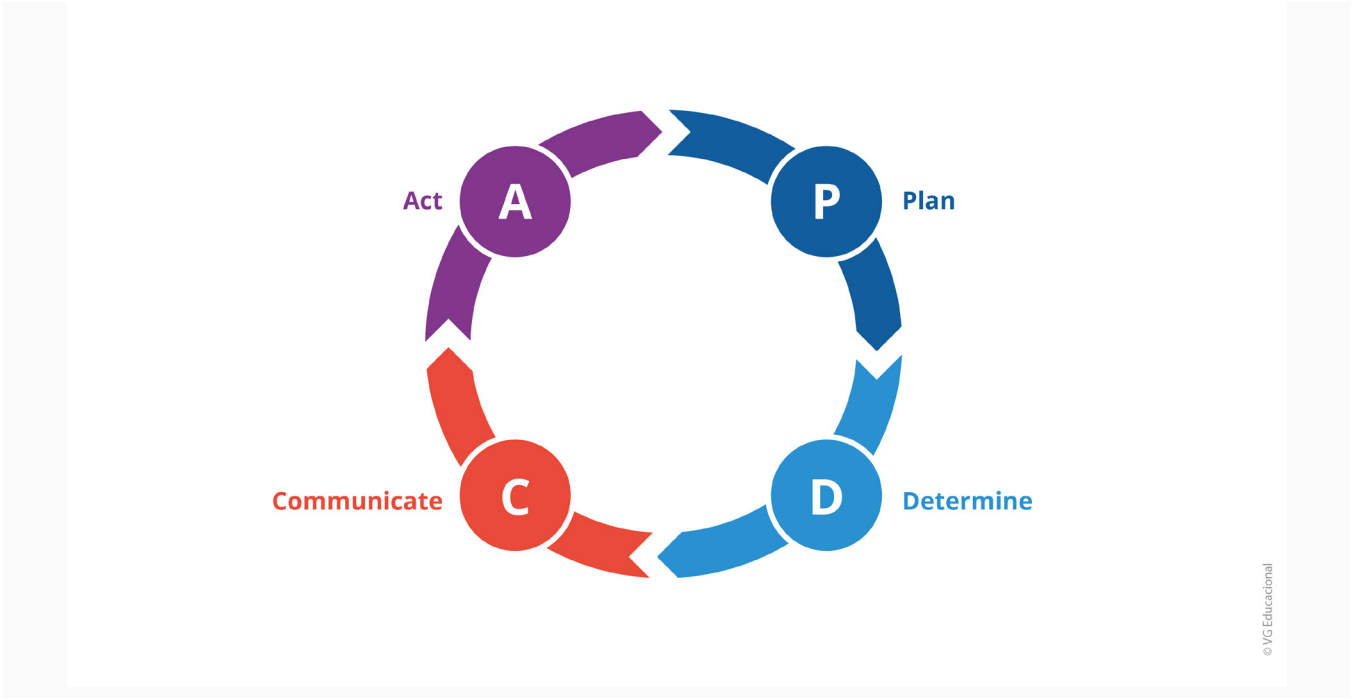
Faced with this challenge, Siqueira (2024) points out that "beyond academic training, the tutor must exercise socioemotional skills and competencies compatible with the challenges of DE, needing to be capable of overcoming the inherent difficulties of the educational process in this modality." Thus, for the consolidation of tutoring work in the teaching of Physics, it is necessary for the tutor to have a certain familiarity with the discipline's content, making it essential that they hold training in the area or a related field, ensuring congruence with the pedagogical work of the teacher.

At the same time, the tutor must strategically plan and carry out their work by observing signs in students indicating (1) lack of motivation in classes and activities, (2) unsatisfactory results in tests and assessments, (3) difficulties with algebra, (4) poor conceptual mastery of the content, (5) absenteeism in synchronous activities, (6) difficulty expressing ideas and concepts, (7) problems solving challenges, (8) low participation in group activities, (9) disinterest in activities involving problem-based learning, and (10) resistance to the teaching and learning process. Previously, we have listed some points of attention that may indicate to the tutor certain difficulties experienced by students throughout the Physics learning process, though these are not the only possibilities given the dynamic nature of the population involved.

Analyzing each of these points, for students with limited conceptual and algebraic background to understand Physics content, classes and activities become uninteresting, leading to demotivation and consequent absenteeism, which in turn results in unsatisfactory performance in tests, assessments, and activities in general (Oliveira; Andrade; Siqueira, 2018). When such a scenario is identified, the tutor can map the degree of difficulty faced by students in understanding the content, comparing it with the results of the pre-test conducted by the teacher, classifying the mathematical content and the more abstract concepts whose comprehension requires greater attention and prior knowledge (Sousa, et al., 2022).

To address the challenges inherent to teaching Physics in distance education (DE), the tutor must implement a systemic pedagogical approach based on a specific sequence of organizational and interventive actions, comprising the following steps: (1) planning, which involves reviewing the pre-test (when conducted) and other mapping activities performed by the instructor, classifying the potential difficulties students face regarding the content to be covered; (2) determining, where, by gathering initial contacts, experiences, and student outcomes, the tutor can initiate their pedagogical intervention by specifying the necessary actions; (3) communicating, in which, once the tutor has sufficient information to begin the intervention, they align their efforts with the instructor to ensure unity and cooperation; and finally, (4) acting, during which the tutor implements the pedagogical plan with the goal of improving student learning. These stages constitute the sequence illustrated in Figure 1.

Figure 1 – Sequence of Tutor Actions for Enhancing Physics Learning



Source: Authors (2024).

Once the action phase is completed, the tutor can critically and reflectively analyze the results, considering the students' learning history, replanning their actions and what will be implemented next, communicating and acting in an interventive manner. This process generates cycles in which the outcomes obtained and the reflection on the actions serve as fundamental guiding elements. Concurrently, the tutor must be attentive to situations where resistance to the teaching and learning process occurs, employing socioemotional skills and psychological principles to address such challenges (Machado, 2019). While it is not expected that the tutor be an expert in human behavior, certain behaviors inherent to the educational process intersect with psychological foundations and are classically used to strengthen the teaching process (Dias, Patias, & Abaid, 2014). When the tutor is able to overcome these situations, students tend to participate more frequently in collective activities, reinforcing the concept of collectivism and shared learning, where individuals build learning relationships that fill gaps and enhance ongoing learning.

5. DIGITAL TECHNOLOGIES AND THE TEACHING OF PHYSICS IN DISTANCE EDUCATION

Digital technologies have been revolutionizing teaching and learning processes, diversifying pedagogical practices and expanding didactic possibilities in response to the imperatives and challenges of the classroom (Oliveira, 2023; Montserrat et al., 2020). Specifically, in distance education (DE), the use of these resources has become increasingly prevalent, as the Virtual Learning Environment (VLE)

naturally incorporates their potentialities and characteristics. Thus, the use of digital tools—such as videos, podcasts, animations, simulations, hypertexts, and other interactive resources—enables the instructor to extend their teaching possibilities, enriching the didactic process, overcoming obstacles, and bringing students closer to the learning experience. According to Santos (2016, p. 5), "digital technology can be a tool to support teaching and learning processes, and its use leads humans to create new cultural instruments, thereby mediating social relationships." Regarding the use of digital information and communication technologies (ICTs), Siqueira (2023a, p. 81) emphasizes the profound impact ICTs have on our collective life and educational processes, bringing into focus the National Common Curricular Base (BNCC) and its paradigms in relation to the use of these technologies in teaching. According to the author:

> All organizational sectors of contemporary society depend on digital technology for their operation; simultaneously, the average citizen must understand and utilize these resources to maintain their life as an organic element of this society, characterized by connectivity and rapid information exchange. In this context, education has been irreversibly impacted by information and communication technologies (ICTs), reshaping teaching practices through the National Common Curricular Base (BNCC), which emphasizes the importance of ICTs in education as a fundamental element in the construction and dissemination of knowledge.

As Distance Education is a modality dependent on communication means for the effective implementation of the teaching and learning process, the use of ICTs directed toward Physics education assumes a specific dimension in light of the learning objectives of this discipline. The choice and utilization of these didactic tools are decisive for the learning of its content. Thus, the delimitation of content and learning objectives will guide the didactic use of these tools. In addition to this context, the teacher can select online tools, such as simulators (PhET Colorado, Vascak, Physion, among others), freely available on the internet, enhancing the teaching process through synchronous and asynchronous activities, promoting deductive use by the student while reinforcing the physical concepts presented in each topic.

Based on the teacher's instructional objectives, such technologies can assist students in solving practical problems, as online simulators are capable of reproducing often complex physical scenarios and conditions. The manipulation of the involved variables allows for the analysis of the behavior of the physical quantities at play, enabling the identification of concepts and their application in problem-solving (Silva; Souza; Lopes, 2023). It is important to emphasize that the use of these tools should occur alongside other materials and resources, such as texts, hypertexts, exercise lists, virtual tests, synchronous and asynchronous classes, constituting a supplementary tool in the teaching process. It is the teacher's responsibility to select and strategically organize the use of these simulators, ensuring didactic consistency and cohesion in teaching practice, balancing the overall implementation of resources. Considering ICTs and their impact on teaching, Siqueira (2023c, p. 2608) highlights that:

> In general, ICTs represent an important disruptive instrument in the pedagogical field, deepening discussions and generating didactic possibilities never before provided by traditional resources. This evolving and valorized scenario prioritizes the student and their

> protagonism in the pursuit of their own education, where cyberspace plays a predominant role in the student's interaction with knowledge, making them not only a receiver but also a critical developer—capable and required to participate actively in virtual communities, strengthening their culture, sharing values, and affirming their identity.

As an example of active engagement, the teacher can plan experimental activities with students using digital video tools, fostering knowledge about the use of these tools by the students themselves, who become authors of their own learning (Paradela et al., 2020). Divided into groups, students can conduct experiments and record their activities through educational videos, editing them under the teacher's guidance, who can emphasize key points such as (1) the didactic quality of the video, (2) the organized and strategic use of digital resources, (3) conceptual consistency of the explanations, (4) integration among group members, and (5) problem-solving of proposed tasks. This approach can complement teaching activities where the theoretical content is dense and highly abstract, requiring not only the use of online simulators but also the active involvement of students in producing videos that bridge theory and materiality.

Another collaborative possibility among students is the creation of blogs or websites using free platforms. These environments, in addition to offering numerous resources for constructing communicative objects, allow students to integrate the Physics content developed within the Virtual Learning Environment (VLE) in an organized, didactic, and creative manner. This makes it possible to build complex virtual spaces that remain accessible to students. Parallel to this, the use of free gamified platforms for teaching Physics reflects a current trend in digital information and communication technologies (TDICs) that emphasizes the application of games in education (Silva; Sales; Castro, 2019). Within the VLE, the use of games increases student engagement, especially through game mechanics that can simultaneously develop different player skills and reinforce Physics content. TDICs encompass a wide range of possibilities for teaching Physics in distance education, allowing the teacher to constructively explore the discipline's content. The teacher's planning is embedded in their knowledge, instructional objectives, and creativity, enabling the creation of didactic events aligned with scientific education and the specific characteristics of Physics.

6. FINAL CONSIDERATIONS

Based on the reflections proposed throughout this research, we conclude that teaching Physics in distance education (DE) constitutes a significant pedagogical challenge, mobilizing different dimensions of the work performed by both teachers and tutors. It requires the strategic use of digital teaching tools that align with the content and objectives established by the instructor. For meaningful learning of Physics in DE, it is necessary for the teacher to have broad conceptual mastery of the content, alongside continuous mapping and intervention by the tutor, who must interpret the main difficulties faced by students at various stages of the teaching process.

In parallel, we highlight the importance of collaborative work between teachers and tutors, allowing pedagogical actions to be focused through the tutor's ongoing analysis of the learning process. This collaboration not only brings unity and cohesion among the actors involved in the

teaching process but also enables continuous reflection on teaching practices—an essential factor for consolidating substantive student learning.

Consequently, Physics content becomes engaging, connected to reality, and assimilable when teaching practices become active through teacher protagonism, reinforced by digital possibilities and tutor mediation. We also conclude that digital technologies represent a valuable resource for didactic transposition in DE, capable of reinforcing autonomous learning as well as teacher protagonism, given the reach of these tools in simulating abstract physical problems and phenomena.

Therefore, knowing and mastering the possibilities offered by digital resources is not only an important step in instructional planning but also a critical teaching strategy that must be connected to the nuances of the content addressed and the instructional objectives.

Furthermore, we conclude that teaching Physics in distance education (DE) constitutes a valuable research problem within the educational field mediated by digital technologies, presenting its own dynamics in light of the inherent teaching challenges of this discipline. Establishing means capable of leading students to meaningful learning of Physics in DE necessarily involves the adoption of active methods linked to digital technologies, as well as evaluation methods capable of indicating students' progress and reinforcing their learning.

In this context, the learning of Physics in DE encounters paradigms and tools that allow for the development of its content in a meaningful way when employed in an integrated, systematic, and strategic manner.

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