

Analyzing the history of physics education in the USA and Europe through natural language processing

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This study systematically explores the thematic evolution of articles in *The Physics Teacher* and *Physics Education* journals during a critical period in modern history, from the Cold War era to the prepandemic world (1966–2019). To contextualize the analysis, we first present an overview of historical events and developments that have characterized physics education in the United States and Europe since the 1950s. Using a natural-language-processing-based inductive topic modeling approach, we then identify recurring themes that have shaped physics education literature, including content-based topics, teaching methodologies, laboratory practices, curriculum development, and the influence of physics education research (PER). Our findings reveal both overarching trends and distinct thematic preferences between the journals. *Physics Education* has historically emphasized curriculum structures, social aspects of education, and interdisciplinary connections, whereas *The Physics Teacher* has focused more on pedagogical strategies, demonstrations, and practical teaching tools. In the last three decades, both journals have increasingly incorporated discussions on technology, computation, and PER-driven instructional practices. By tracing these shifts over five decades, this study provides a broader perspective on how physics education has responded to changing educational priorities, technological advancements, and research developments.

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I. INTRODUCTION

The field of physics education has a long and rich international history. In both Europe and the United States, physics education in its current form has been established for well over half a century, dating back to efforts in the 1960s to create standardized curricula that could apply across universities and could help high schools understand how they should prepare their students for university studies [1–3].

In the United States, these efforts were spurred on by the Cold War, which motivated the U.S. government to invest significant resources in science education in order to build a competitive scientific workforce [4]. During that same period, European countries also worked to improve their science education curricula as part of broader efforts to establish Europe as a technological and scientific power and as a critical component of Europe’s technological development. This development was driven in part by Cold War dynamics, which reinforced the strength of European nations to maintain competitiveness with both the United States and the Soviet Union [5].

Around the same time, physics teaching journals were launched in both the United States and Europe. In the United States, *The Physics Teacher* (TPT) published its first issue in 1963, going on to publish a diverse range of articles, from pedagogical contributions for the teaching of fundamental physics concepts to historical perspectives to explore experimental breakthroughs in physics. Many of TPT’s articles aimed to make physics engaging, show its application in everyday life, or provide detailed descriptions of innovative experimental setups for classroom instruction (i.e., “*Apparatus for Teaching Physics*” series). Shortly after, in the United Kingdom, *Physics Education* (PE) published its first issue in 1966, with articles focusing on both conceptual and practical aspects of teaching physics. For example, articles explored effective teaching strategies for diverse physics topics such as dynamics and special relativity, provided a guide to design effective physics experiments, and illustrated common misconceptions in physics, alongside articles more focused on interdisciplinary aspects of physics and the historical and philosophical evolution of the discipline.

These journals are similar, since both made an early commitment to exploring both theoretical and applied aspects of physics education, serving as a resource for teachers and students alike. Their publication activity has continued uninterrupted to the present day. As of 2020, *The Physics Teacher* has published approximately

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15,000 articles, and *Physics Education* has published around 7000. This body of literature holds the potential to reveal many interesting aspects of how physics teaching and learning have evolved over the period of publication. However, the scale of the literature has made it intractable to do traditional, by-hand literature reviews.

If this literature could be analyzed, it would help us understand the themes addressed by the two journals over time, highlighting shifts in interests and the types of materials they have provided to the community of teachers and researchers. Additionally, we could examine the differences between the two journals, each of which, despite covering similar topics, has its own unique identity and focus. Analyzing these aspects could offer a broad perspective on the evolving landscape of physics teaching, which, in various ways, has been reflected in the articles they have published. The selection of topics and articles has likely been influenced by topical events and prevailing interests in the field. Furthermore, given that the two journals focus on different geographical areas, that is, the North American context for *The Physics Teacher* and the European one for *Physics Education*, such a study may also reveal differences shaped by their respective educational systems.

In this article, we conduct a thematic analysis of over 50 years' worth of articles published in these two journals using a technique from the field of natural language processing, Latent Dirichlet allocation (LDA). In brief, we have integrated LDA into a qualitative thematic analysis to identify key themes in the articles in order to characterize thematic trends of the two journals over time. This analysis reveals topics addressed by the journals, mapping interests that were related to both the historical context and evolving needs of the field.

In what follows, we begin with the background for the study and an overview of the literature, where we situate this study within the history of physics education and introduce the two journals (*The Physics Teacher* and *Physics Education*) in Sec. II. Additionally, we introduce the LDA method and highlight its previous applications within the field of science and physics education research. In Sec. III, we outline the aims and research questions guiding our study. Section IV contains a detailed description of our methodology, where we explain how we processed the data and performed the inductive thematic analysis. In Sec. V, we present the results of our analysis, beginning with an overview of the topics discovered across both journals combined. We then explore distinct trends within each journal separately, revealing peculiar interests and educational contexts in North America and Europe. Finally, in Secs. VI and VII, we discuss the implications of our findings, highlighting the differences and similarities revealed between the two educational systems and providing conclusions on the evolving discourse in physics education over time.

II. BACKGROUND AND LITERATURE REVIEW

A. Overview of the history of physics education

In this work, we aim to thematically investigate literature on physics education from the 1960s to the present. Thus, it is useful to contextualize this study with a discussion of significant events and important shifts in physics education over this period. We base this discussion on the work of Otero and Meltzer [4], which provides a historical description of developments in U.S. physics education since the 1800s, as well as a dedicated chapter in the book “125 Years: The Physical Society & The Institute of Physics” which provides context to the development of physics education in Europe [6].

Physics education has shifted through several different phases over its history. Within the United States, in the years following World War II, the political and social importance of science and technology grew, particularly because of the Cold War. This led to substantial investment in science education. For example, the establishment of the National Science Foundation (NSF) in 1950 and the launch of Sputnik in 1957 triggered a rapid expansion of teacher training programs and the development of new high school physics curricula, such as the Physical Science Study Committee (PSSC) (1956) and, later, Project Physics (active from 1962) [7]. These programs aimed to foster a more conceptual and inquiry-based approach to learning.

During the 1960s and 1970s, efforts to improve physics education focused on teacher training and the creation of innovative teaching materials. The Commission on College Physics, founded in 1960 with the support of the NSF, worked to enhance physics instruction at the university level and improve the preparation of high school teachers. In 1972, the National Research Council recommended inquiry-based physics courses for teacher training. However, many of these efforts remained limited to a relatively small portion of the educational system.

A significant driver of change emerged during the 1970s and 1980s, when Physics Education Research (PER) began to establish itself as an academic discipline. Scholars such as Arons and Karplus advocated for the use of inquiry-based teaching methods [8]. Meanwhile, researchers like McDermott at the University of Washington began developing educational programs based on systematic studies of students' learning difficulties [9]. A key moment came in the late 1980s with the development of the Force Concept Inventory (FCI) (1985) [10,11], a diagnostic tool for assessing students' understanding of mechanics.

A defining feature of the 1990s was the rise of conceptual physics, which emphasized qualitative understanding over mathematical formalism. This contributed to a significant increase in high school physics enrollments [4]. At the same time, computational physics gained prominence, driven by advances in computer technology and the growing recognition of computation as a third pillar of

scientific inquiry alongside theory and experiment [12]. Graphical modeling tools and simulation software became increasingly integrated into physics education, allowing students to visualize complex systems, explore dynamic interactions, and develop an intuitive grasp of physical principles. By shifting the focus from purely analytical methods to computational approaches, these tools expanded access to physics learning and reshaped the way students engaged with scientific problem solving.

Returning to the role of PER, from 2000 onward, it gained greater academic recognition. Studies such as that of Hake [13] demonstrated that active learning and research-based methodologies lead to significant improvements in student learning. As a result, many universities began implementing innovative teaching strategies, including the use of technology in laboratories and learning based on multiple representations. The impact on teaching was evident even before, from the 1990s onward, as the integration of PER findings into classroom practice led to the development of research-based curricula and interactive engagement techniques. This shift was also reflected in the dissemination of research literature, which, as McDermott and Redish noted in 1999 in the *American Journal of Physics*, aimed to serve not only physics education researchers but also “*the much larger community of physics instructors whose primary interest is in using the results from research as a guide for improving instruction*” [14]. Today, physics education in the United States continues to evolve, balancing technological advancements, diverse student needs, and ongoing debates about the most effective ways to teach and learn the subject.

Within Europe, the 1950s were characterized by a period of significant stagnation for physics education [6]. Physics teaching commonly relied heavily on rote memorization, with students expected to memorize formulas, definitions, and experiment descriptions, and little focus on fostering critical thinking or inquiry. This traditional approach limited the scope of learning and created a disconnect between the rapidly evolving field of physics and the methods used in the classroom. Although there were some localized efforts to innovate, such as the introduction of new experimental apparatus through the Nuffield Physics Projects in the late 1950s, the overall impact of these initiatives was gradual and often impeded by the inertia of long-standing teaching practices.

However, the post-WWII period also marked the beginning of important shifts that would gradually transform European physics education. One key event was the founding of CERN in 1954, which was driven by the ambition to challenge American leadership in scientific research. CERN’s establishment symbolized Europe’s commitment to scientific innovation and international collaboration, laying the foundation for a more modern and dynamic approach to science. This development was not only crucial for advancing high-energy physics research

but also influenced the educational landscape, signaling the need for an overhaul in how physics was taught in Europe.

In the 1960s, Physics education in Europe began to change. The exchange of knowledge with the United States, especially through models like the aforementioned Project Physics Course, played a significant role in introducing new teaching approaches. These American-led initiatives, combined with U.S.-led science policy, heavily influenced European physics education, particularly in high-energy physics research. At the same time, European countries recognized the need to foster their own technological advancements, resulting in the launch of several initiatives designed to strengthen scientific knowledge across the continent. One such example was CERN’s *Science for All* program [5], organized since the 1960s to engage nonacademic staff in scientific discussions, reflecting a broader movement to disseminate scientific knowledge and build a stronger scientific workforce in Europe.

This decade, therefore, marked a turning point for physics education in Europe, as efforts to modernize the curriculum and teaching methods gained momentum. The Nuffield Physics Project, the development of which was influenced by the Physical Science Study Committee (PSSC), gained more traction. It represented a significant step toward a more inquiry-based, student-centered approach to learning, emphasizing the importance of developing students’ critical thinking skills and moving away from rote memorization. In fact, both PSSC and Nuffield Project reforms placed greater emphasis on the process of science, encouraging students to think like scientists rather than merely recalling facts [15].

Between the 1970s and 1980s, European physics education, especially in the United Kingdom, saw significant reforms, largely driven by the Institute of Physics (IOP). The IOP helped establish several key committees, producing reports on issues, such as *the shortage of physics teachers*, *resources for teaching school physics*, and *interface between physics, mathematics, and engineering*. There was general support for mature students to earn a physics degree. Amidst these changes, the shortage of qualified teachers became a major concern, prompting governmental action. In 1988, the publication *Physics in Higher Education* led to the introduction of the four-year MPhys/MSci degrees, shifting focus toward professional training for physicists [6].

In the 1990s, the United Kingdom faced a significant decline in the number of students taking A-level physics, a trend that raised concerns about the future supply of skilled scientists and engineers. Recognizing the need to attract more young people to physics, the IOP launched the 16–19 Physics Initiative in 1997. This initiative aimed to make physics courses more engaging, modern, and relevant, beyond just revising syllabuses. This effort was seen as essential for ensuring a high-caliber workforce for the future [6].

Across these shared histories, we note several interesting trends. First, philosophy and history have played significantly different roles within physics education systems of the United States and Europe. As Bevilacqua and Giannetto describe [16], in Europe, the postwar period was marked by a division between the humanities and the sciences. However, for physicists with a classical education acquired during high school, this cultural split was not entirely accepted or embraced. In some ways, it prompted the scientific community to engage in historical and philosophical debates, fostering a strong interest in foundational philosophical questions and a well-established tradition in the history of physics. This tradition reached its peak around 1950 but remained deeply influential in the following years.

In the United States, Kuhn's influential distinction between "normal" and "revolutionary" science, introduced in *The Structure of Scientific Revolutions*, sparked significant debate. While his work was not a direct critique of textbook science, it was later interpreted by some scholars as challenging the static portrayal of science found in textbooks. This contributed to a distancing of U.S. historians of science from the field of education, as reflected in the 1970 MIT meeting. In contrast, from the 1980s onward, Europe increasingly integrated history and philosophy into physics education, embracing a broader intellectual tradition [16].

Second, both systems have seen major shifts in the role of laboratory instruction and instructional use of experiments, tools, and software. According to May [17], in the post-WWII period, the physics education community critiqued traditional "cookbook" labs, which led to debates about better aligning labs with conceptual learning goals and experimental skills. This period saw the rise of more student-centered approaches, with innovations like "free" and guided inquiry labs, where students explored experiments with more autonomy. The American Association of Physics Teachers (AAPT) played a key role, releasing lab recommendations in 1957, promoting the shift away from rigid procedures to more exploratory learning.

In the 1970s and 1980s, technology integration, such as computers and simulations, enhanced data collection, analysis, and measurement uncertainty studies. Meanwhile, PER began assessing the effectiveness of these new methods [18,19], shifting focus from traditional assessments like written exams to more practical, performance-based evaluations.

By the late 20th century, evidence-based lab reforms were introduced, emphasizing goals such as hands-on experimentation, conceptual understanding, and collaborative skills. The AAPT's 1998 report [20] outlined these as key goals for introductory labs, marking a shift from "how" labs were structured to "what" they aimed to achieve. This period also saw further innovation in lab design, with increasing use of computational tools and troubleshooting

skills. The focus was increasingly on student-driven exploration and data analysis, laying the groundwork for the more interactive and technology-integrated physics labs of the 21st century.

This history provides a useful context for the present literary analysis. The main events and contexts discussed so far are summarized in Table I to facilitate easy reference and map key developments in physics education from the post-WWII era to the pandemic period, which we will revisit when presenting our results.

We now move to the analysis. The selected literature for our study consists of a large collection of articles from two journals that share similar objectives but were founded by different societies and serve different communities. Specifically, we examine publications from *The Physics Teacher* and *Physics Education* from their inception until the pandemic. Below, we summarize key characteristics of these journals, including their publication period, affiliated societies, and article styles and targets.

B. Literature: The physics teacher and physics education

1. *The Physics Teacher*

Launched in 1963, *The Physics Teacher* is published by AIP Publishing on behalf of the *American Association of Physics Teachers* (AAPT), an organization that has played a central role in advancing physics education since its founding in 1930.

Established by Homer L. Dodge, Paul E. Klopsteg, and William S. Webb, AAPT was created with the goal of improving physics teaching and the dissemination of physics knowledge. Over the decades, leading figures such as Melba Philips helped emphasize the idea that effective teaching is essential not only for scientific progress but also for a broader societal benefit. Through *The Physics Teacher*, AAPT provides educators with research-based insights, classroom strategies, and discussions on contemporary challenges in physics teaching.

The journal publishes short peer-reviewed articles covering a wide range of topics, such as the teaching of introductory physics, contemporary and applied physics, and the history of the discipline. Its content and materials are designed for educators at all levels, including secondary schools, colleges, and universities. For this study, we had access to its complete corpus of publications from its inception to 2020.

2. *Physics Education*

Physics Education is an international journal dedicated to advancing the teaching and learning of physics. *Physics Education* is published by IOP Publishing on behalf of the Institute of Physics (IOP), and its first publication was in 1966. IOP is a UK-based professional organization that promotes physics research, education, and outreach.

TABLE I. Summary of historical events and contexts that shaped physics education in the United States and Europe, based on Otero and Meltzer [4] and Lewis [6].

1950s	• Post WWII • Cold War • Sputnik launch • CERN Foundation (1954) • National Science Foundation • PSSC • Development of high school and university physics curricula • General stagnation for European physics education
1960s to 1970s	• Project Physics (1962) • Conceptual and inquiry-based approach to learning. • Focus on teacher training • Development of teaching material • Science for all at CERN • Diffusion of Nuffield Science (and Physics) Project (1957)
1980s	• Establishment of Physics Education Research as an academic discipline • Studies on students' learning difficulties • Force Concept Inventory (1985) • Shortage of Physics teachers in Europe • 4-year degrees in physics
1990s	• Conceptual physics and qualitative understanding over formalism • Rise of computational physics • Simulators included in physics education • Integration of PER findings into classroom practice
2000s–2010s	• Student-driven exploration • Innovation in lab design: computational tools and interactive, technology-integrated physics labs • Focus on students' skills (e.g., troubleshooting skills) • Results from research as a guide for improving instruction

Unlike *The Physics Teacher*, which primarily serves the North American physics education community, *Physics Education* has a broad international readership. It focuses on practical approaches to teaching physics at the secondary school and early undergraduate levels, publishing peer-reviewed articles that explore novel instructional strategies, experimental techniques, curriculum design, and technological advancements in education.

The journal covers a wide range of topics, including hands-on experiments and demonstrations, the use of technology in physics education, and conceptual understanding, along with common student misconceptions. Moreover, the journal highlights additional insights, such as interdisciplinary applications of physics and historical and philosophical perspectives on physics teaching.

Over the years, *Physics Education* has featured special issues and thematic collections addressing emerging trends in physics education, such as the integration of computational tools, online learning environments, and inquiry-based teaching approaches. The journal has remained a valuable resource for educators worldwide, providing both theoretical insights and practical guidance for classroom implementation. For this study, we had access to *Physics Education*'s entire publication history from its launch in 1966 to 2024.

C. LDA theory and prior work

1. Introduction to LDA

Latent Dirichlet Allocation (LDA) is a widely used probabilistic generative model for topic modeling, originally introduced by Blei *et al.* [21]. It is a technique developed within the field of natural language processing (NLP), a subfield of machine learning that focuses on the recognition and analysis of language and text. LDA is an unsupervised learning method, meaning that it discovers patterns in text without requiring manual labeling or predefined categories [22]. This makes it a powerful tool for uncovering hidden thematic structures in large collections of textual data.

At its core, LDA assumes that each document contains a mix of topics, and each topic is characterized by a distinct set of words with varying probabilities. In other words, when writers use a similar set of words frequently within a text, they are likely discussing the same underlying topic. For example, if a document frequently contains words like “planet,” “orbit,” “gravity,” and “telescope,” it is likely discussing astronomy. However, LDA also assumes that documents are not strictly about a single topic; rather, each document is a blend of multiple topics to different degrees. For instance, an article on space exploration may be

composed of 70% astronomy-related words and 30% engineering-related words.

LDA functions by representing documents using a “bag of words” (BoW) approach, where the order of words is ignored, and only their frequency is considered. The algorithm then tries to group words that frequently co-occur across multiple documents into latent topics. These topics are not predefined but rather inferred from statistical patterns in the data [23]. Once the topics have been identified, LDA outputs them as lists of words weighted by their importance to the topic. Researchers must then interpret these lists to determine the actual meaning of each topic.

One of the most useful aspects of LDA is its ability to calculate topic prevalence across a dataset. By analyzing the proportion of each topic in each document, researchers can identify how themes have evolved over time or how they differ between various sources. For example, in an analysis of physics education research, one might observe that discussions about computational methods have increased in recent years, while interest in traditional laboratory-based instruction has declined [24,25].

While LDA is a powerful tool, it requires researchers to make several decisions, including the number of topics to extract, how much overlap to allow between topics, and how to preprocess the text (such as removing common words like “and” or “listen”). Additionally, because LDA is a probabilistic model, results may vary slightly between runs, requiring careful validation and interpretation [26].

2. Previous applications of LDA to Science and Physics Education Research

Several studies have applied LDA to analyze educational literature, demonstrating its potential for large-scale thematic review, classification, and trend analysis. Below, we summarize key works that have utilized this method to study different aspects of science and physics education research.

One of the most comprehensive applications of LDA in science education is the work of Odden *et al.*, published in 2021 [27], who used topic modeling to analyze over 100 years of publications in the journal *Science Education*. Their study identified 21 distinct topics in the science education research literature, grouped into three broad categories: science content, teaching-focused, and student-focused topics. By tracking topic prevalence over time, they revealed how national policies, intellectual shifts, and interdisciplinary influences have shaped the field. Their findings suggest that LDA can effectively capture long-term trends and provide insights into the historical development of educational research.

In PER, Odden *et al.* in 2020 applied LDA to 18 years of Physics Education Research Conference (PERC) proceedings [25]. They identified ten recurring themes in PER,

showing how research interests evolved from early qualitative studies of student understanding to later emphases on problem solving and, more recently, sociocultural perspectives on teaching and learning. Their work highlights the usefulness of LDA in detecting waves of intellectual focus within a research community.

Building on these efforts, Odden *et al.* [28] extended the use of natural language processing for PER literature analysis by integrating text embeddings with LDA results. This approach allowed them to redefine topic structures and perform a deductive qualitative analysis at scale. By mapping articles into a high-dimensional semantic space, they demonstrated how topic modeling can be augmented with additional machine learning techniques to enhance interpretability and researcher-defined classifications.

III. AIMS AND RESEARCH QUESTIONS

While these previous studies have successfully used LDA to examine trends in science and physics education research, they have primarily focused on *research* literature rather than *teaching*-focused journals. Moreover, prior analyses have largely centered on either a single journal (e.g., *Science Education*) or conference proceedings (PERC), leaving a gap in understanding how educational discourse has evolved across different journals specifically aimed at physics educators.

In this study, we apply LDA to *The Physics Teacher* (TPT) and *Physics Education* (PE), two long-standing journals dedicated to physics teaching. Unlike previous work, which primarily analyzed physics education research literature, our focus is on the thematic evolution of physics teaching practices, curriculum development, key physics contents, and instructional strategies, as reflected in these journals. By conducting a comparative analysis of TPT and PE, we aim to uncover how physics teaching priorities and methodologies have changed over time and across different educational communities.

Our research questions are as follows:

1. What topics can be discovered in the corpus of articles composed of all articles published in *The Physics Teacher* and *Physics Education* journals from 1966 through 2019? What characteristic trends about physics teaching can be recognized, how they have evolved, and what is their prominence in this ensemble of articles?
2. To what extent are the discovered topics covered by the two journals separately? Are there specific trends or interests that differentiate the two journals?
3. Considering the reference literature, what do these topics and their trends tell us about the differences and similarities between the two educational systems (European and North American) regarding the teaching of physics?

IV. METHODOLOGY

To answer these research questions, we performed two analyses:

1. An inductive LDA analysis of the complete dataset, which includes both TPT and PE articles, to identify topics covered by the two journals.
2. A quantitative analysis of the results from the inductive LDA analysis, where we separated the data by TPT and PE articles to identify differences between the two journals.

It is important to note that before conducting the inductive analysis of the complete dataset, we carried out exploratory LDA analyses on each journal independently. While these individual analyses are not the focus of this work, they informed several decisions in the analysis of the complete dataset. For instance, when determining the number of topics, we considered that each journal independently revealed at least 15 topics, which guided our selection of the minimum number of topics to explore in the combined dataset.

Below, we provide a detailed description of the methodology.

A. Inductive thematic analyses using LDA

Our general method for topic analysis using LDA consists of three main steps: (i) dataset creation and text preparation, (ii) development and testing of the LDA model, and (iii) topic interpretation and trend visualization.

1. Dataset creation and text preparation

The creation of the dataset and adjustment of the text are the first crucial steps in the analysis process. This phase involves organizing and preparing the textual documents, formatting them in a way that can be more easily processed by the machine. We note that the TPT and PE articles were retrieved in two different years, so any differences in handling the articles from the two journals will be highlighted below.

PDF-to-text conversion: We first downloaded all published articles in PDF format from both journals. These PDFs were converted into text documents using Adobe Acrobat. The TPT articles were retrieved in mid-2020, and the PE articles in late 2024. The extracted text was then organized into a structured table with associated metadata such as article titles, publication years, authors, and DOIs.

Initial data curation: Next, we filtered articles based on relevance for the analysis, removing those primarily focused on journal business (announcements, editorials, and advertisements), assuming that they offered minimal value to our research objectives. Specifically, we removed documents with very short texts (under 400 characters), articles without author information, duplicates, and articles with problematic formatting. Additionally, articles with

specific headers, such as “ANNOUNCEMENT”, “BOOK REVIEWS”, and “NEWS” were excluded.

Article exploration: To confirm proper retrieval of data and gather information for further refinement of the dataset, we next examined the TPT and PE datasets. First, we conducted a general survey of the articles, noting that those from PE appeared to have higher fidelity extraction of titles and formatting than TPT articles. One possible reason for this is that retrieval libraries were improved over the 4-year period between TPT and PE text extraction.

Next, we examined the two datasets to identify journal-specific article series or types, which should be included in or excluded from the final dataset. By reviewing the most common bigrams and trigrams in the titles, we identified recurring series such as “NOTES”, “Apparatus for teaching physics”, and “Research frontier” in TPT, and “PEOPLE”, “Reviews”, and “Letters” in PE. We also examined the articles’ content and noted that some text unrelated to the article itself often appeared before or after the main body of the article. This was because of the fact that many articles were printed in a magazine format, in which the end of the previous article was included on the first page of the main article’s PDF.

Based on these findings, we proceeded with a second data cleaning step.

Second round of data curation: Based on the RQs, we included articles relevant to the journals’ specific interests (e.g., “Apparatus for Teaching Physics”) and excluded those related to journal business or book reviews, maintaining consistency with the first cleaning step. Therefore, we removed articles with specific terms in the titles, such as “Correction”, “BOOKS FOR YOUNG PEOPLE”, and “Erratum” for TPT, and “News”, “PEOPLE”, and “book review” for PE.

Moreover, articles missing author information or text, as well as those shorter than 500 words, were excluded, under the assumption that longer articles provide more in-depth treatment of topics.

Finally, in order to remove redundant text because of the journals’ magazine format, we filtered out the text preceding each title. This step significantly improved the data, as over 5000 articles in each journal were corrected at this stage.

This led to the removal of 55 articles from TPT and 252 from PE. The final dataset then contained 6445 articles from PE and 7203 from TPT. This set of 13,648 articles constituted our data corpus.

Dataset limitations and potential impact on the LDA model: The dataset’s limitations stem primarily from challenges with TPT’s older articles, particularly those published before digital typesetting. These articles often contained OCR (optical character recognition) errors, which we identified through a random selection process. A common issue was the incorrect merging of sections, as some older PDFs consisted of scanned images rather than

selectable text. To estimate the extent of this problem, we grouped articles by year and reviewed a random sample. Our qualitative exploration revealed that articles published before 1978 were most affected by these errors.

These OCR-related issues limited our ability to retrieve text in a more organized form and to remove undesired text that was incorrectly included. Consequently, the quality of the text in these older articles may influence the prevalence of specific word clusters identified by the LDA model, particularly for articles published before 1978.

However, it should be noted that in a BoW-based model like LDA, the order of words in a text is not a crucial factor. As such, incorrect merging of sections will not significantly impact the validity of the model's results. Additionally, very short articles were excluded from the dataset, leaving only longer articles where a small amount of anomalous text is unlikely to significantly alter the overall patterns in word usage. Given these considerations, we believe that the impact of these limitations is minimal, and the general validity of the analysis remains intact.

Text preparation for LDA (LDA preprocessing): To ensure consistency and reduce the dimensionality of textual data, we applied a series of preprocessing steps. First, unique identifiers and common section headings (e.g., *introduction*, *methodology*, and *results*) were removed. Next, all newline characters, tabs, digits, and bullet points were eliminated, and nonalphanumeric characters were replaced with spaces. Hyphenated word fragments at line breaks were merged (e.g., “*pre-~~v~~processing*” becomes “*preprocessing*”), and the text was converted to lowercase. Finally, minor lexical corrections were applied, such as fixing typos (e.g., *tlie* to *the* and *per cent* to *percent*). These steps ensured a clean and standardized text for subsequent analysis.

Text tokenization and bigram generation: To prepare the text for analysis, we applied a series of transformations. First, sentences were tokenized into lowercase word sequences while removing accent marks and punctuation. Next, stopwords (such as “if”, “and”, and “but”) were removed to retain only semantically meaningful terms. Lemmatization was then performed using WordNet, where each token was assigned its most relevant part-of-speech tag (e.g., “*matches*” becomes “*match*”) before being reduced to its base form. Finally, bigrams (frequent co-occurring word pairs) were generated to capture multiword expressions (for example, converting “high school” to “high_school”), enhancing contextual understanding in the subsequent analysis.

2. LDA model development and testing

After preparing textual datasets for TPT and PE articles, we used them to develop the LDA model. A series of parameter-tuning steps was implemented to ensure robust and meaningful topic extraction.

Word frequency filtering: Before applying the LDA algorithm, we filtered words based on their frequency across the dataset. Words occurring fewer than 15 times were removed to eliminate rare terms that could introduce noise. Additionally, highly frequent words were excluded based on a dynamic threshold, removing terms appearing in anywhere from 45% to 99% of the documents. We systematically analyzed the lists of removed words at different cutoffs to ensure that important domain-specific terms were retained. For instance, setting a stricter threshold at 40% would have resulted in the exclusion of key terms such as *data*, *measurement*, *observe*, *model*, and *force* (from *Physics Education*), and *data*, *laboratory*, and *motion* (from *The Physics Teacher*).

Topic extraction using LDA and testing: Once data preparation and filtering were completed, we combined the two datasets and proceeded with topic modeling using LDA. We used the open-source Gensim library [29] in Python, in combination with the Natural Language Toolkit (NLTK) [30] for data filtering. While the LDA implementation is straightforward in principle, unsupervised topic modeling presents several inherent challenges:

- **Random initialization**—LDA is a probabilistic model, meaning each run is randomly initialized, which can lead to variations in the extracted topics.
- **Number of topics**—The number of topics must be specified before running the model. Determining the optimal number of topics is not trivial, as too few topics might obscure meaningful distinctions, while too many might result in overly fragmented themes.

To address these issues, we systematically tested different model configurations to find the optimal number of topics and initial seed. We assumed that the number of topics that could meaningfully describe the dataset, composed of both PE and TPT articles, would be at least 15, because this was the number of topics discovered in each journal when analyzed independently. Thus, we tested topic numbers in the range of 15–22.

In this phase, we also computed the topic coherence score [31,32] for each model. Coherence measures how well a model's topics align with actual document content, with typical scores for academic literature ranging from 0.4 to 0.6 [25,32]. The final selection of 20 topics was made by considering both the elbow method (to compute the best coherence score range) and qualitative inspection (to ensure the interpretability of topics). This approach allowed us to ensure that the extracted themes were distinct and representative of trends across both journals.

To further ensure the robustness of our chosen model, we examined topic stability across different random initializations. Following Odden *et al.* [25], we generated 15 models and used a clustering algorithm to average them, selecting the model closest to this average. This model typically had a higher-than-average coherence score. The final model for the combined PE-TPT analysis achieved a coherence score

of 0.577, slightly above the overall average (0.572), which provided additional confidence in its reliability.

3. Topic interpretation and trend visualization

Once the final LDA model was selected, we conducted a face validity check by manually inspecting the most representative words for each topic to ensure coherence and interpretability. The trained LDA model was then applied to the entire set of articles to classify each one in terms of its distribution across all topics. In other words, each article was assigned a percentage for every topic, reflecting the proportion of its content associated with that topic. Based on these distributions, we identified the top 15 documents most strongly associated with each topic (with proportions typically ranging between 60% and 98%). These highly representative articles, together with the top words, were used to assign meaningful labels to each topic. For example, if an article is 89% representative of topic 1, this means that 89% of its content is classified as belonging to topic 1, while the remaining 11% is distributed across other topics. These articles are crucial for interpretation, providing concrete examples that help contextualize each topic and understand the type of contributions it encompasses.

Thus, topic labels were assigned based on the combination of the most representative words and the content of the top 15 most strongly associated articles for each topic. Labels were chosen to be concise and meaningful within the context of physics and physics education: general labels were used for broad topics (e.g., “Newtonian mechanics”), while more specific labels were assigned when a topic focused on a particular aspect (e.g., “Trends in physics education: course structures and career pathways”).

Finally, we explored temporal trends to see how topics evolved over time. For this analysis, we calculated their annual prevalence, averaging topic contributions across all documents per year. By “prevalence”, we refer to the extent to which each topic is represented in the literature for a given year.¹ To smooth fluctuations, we applied a three-year rolling average, preserving major trends while reducing noise.

For this analysis, data were considered between the interval from 1966 to 2019. The endpoint, 2019, was selected because data collection for *The Physics Teacher* was conducted in mid-2020, and we included only the years for which the article collection was fully completed. This time frame allows us to observe the trends of these 20 topics from the second part of the 1960s to the prepandemic period. The year 2020 represents the beginning of a new era characterized by significant events such as the massive e-learning and the advent of artificial intelligence tools in schools.

¹Prevalence has also been referred to as “attention”, denoting the percentage of focus that a particular topic receives within the literature as a whole each year [33].

These methodological choices ensured that our LDA model produced interpretable, reliable, and meaningful topic distributions, which were then analyzed to construct narratives about trends in the literature.

B. Quantitative analysis of topic differences between TPT and PE

Based on the previous LDA analysis, each article was represented as a weighted combination of the 20 identified topics. For this analysis, the data were separated into two distinct subsets: one containing only TPT articles and the other containing only PE articles.

By plotting the trends of topic prevalence over time from 1966 to 2019, we quantitatively assessed the prominence of each topic within the two journals. This approach facilitated a comparative analysis of the thematic focus of TPT and PE, highlighting potential differences in the interests and trends between the two journals over the study period.

V. RESULTS

In this section, first, we show what emerges by analyzing the whole corpus of articles together, in order to have an overall view of the trends in the literature as a whole. Then, in the last section, we present the results of the two separate analyses of articles from *Physics Education* and *The Physics Teacher*, to highlight possible similarities and differences between the journals.

A. Topics discovered in the inductive LDA analysis (1966–2019)

The analysis of the complete TPT-PE literature in the period 1966–2019 has revealed a diverse set of themes that characterize the research published in *Physics Education* and *The Physics Teacher*. These topics encompass both core physics content and broader themes related to physics pedagogy, instructional strategies, and students’ disciplinary learning.

To interpret the topics meaningfully, we considered both the most relevant keywords and some of the articles among the top 15 most strongly associated with each topic (for details, see Sec. IV A 3). The complete lists of these top-15 articles are provided in Appendix. In this section, we describe some of these articles to provide concrete examples that help clarify the themes and significance of each topic.

For better understanding of the results, Table II shows the complete list of topics discovered, and Figs. 1 and 2 present the prevalence of the 20 topics in the dataset of articles over time. The key difference between Figs. 1 and 2 lies in how prevalence is represented. Figure 1 displays the *normalized* prevalence of each topic, providing a view of how each topic and topic group evolved over time as a percentage of the complete literature in that year. In contrast, Fig. 2 presents the *un-normalized* prevalence, showing the aggregate number of articles published for

TABLE II. Topics discovered through the inductive thematic analysis of complete dataset (articles from TPT and PE journals), with corresponding top words. Content-based topics are highlighted in blue (topics 1–14), the topic about history and philosophy of physics in green (topic 15), teaching-focused topics in pink (Topics 16–19), and the learning-focused topic in light brown (topic 20).

Topic number	Topic name	Top-weighted words per topic (LDA model)
Topic 1	Fundamental equations and mathematical principles in physics	2,9% “equation” + 1,0% “constant” + 0,8% “unit” + 0,8% “mass” + 0,7% “term” + 0,6% “equal”
Topic 2	Newtonian mechanics	5,7% “force” + 2,4% “motion” + 1,9% “acceleration” + 1,9% “mass” + 1,8% “object” + 1,7% “body”
Topic 3	Applied mechanics	3,7% “ball” + 2,2% “speed” + 1,5% “velocity” + 1,1% “collision” + 1,0% “fall” + 0,9% “motion”
Topic 4	Fluid mechanics and gas laws	4,6% “water” + 2,5% “pressure” + 2,2% “air” + 1,8% “liquid” + 1,4% “volume” + 1,1% “tube”
Topic 5	Waves and sound	4,7% “frequency” + 3,6% “wave” + 3,1% “sound” + 1,4% “signal” + 1,0% “amplitude” + 0,8% “pulse”
Topic 6	Colour and light	4,9% “light” + 1,8% “image” + 1,5% “colour” + 1,5% “color” + 1,2% “spectrum” + 1,1% “camera”
Topic 7	Optics	2,6% “light” + 2,6% “image” + 2,1% “lens” + 1,5% “mirror” + 1,3% “object” + 1,3% “ray”
Topic 8	Electromagnetism and currents	4,2% “magnet” + 3,0% “magnetic field” + 2,9% “field” + 2,9% “coil” + 2,4% “current” + 2,3% “magnetic”
Topic 9	Electrostatics and atmospheric physics	2,2% “charge” + 1,6% “surface” + 0,9% “plate” + 0,7% “wind” + 0,7% “air” + 0,7% “area”
Topic 10	Circuits and electronics	2,4% “circuit” + 2,3% “voltage” + 2,0% “current” + 1,3% “resistance” + 0,8% “output” + 0,7% “power”
Topic 11	Thermodynamics	5,8% “temperature” + 4,5% “energy” + 2,4% “heat” + 1,1% “power” + 1,0% “cool” + 0,8% “water”
Topic 12	Astronomy	2,7% “earth” + 1,9% “sun” + 1,7% “star” + 1,1% “astronomy” + 1,0% “planet” + 1,0% “space”
Topic 13	Nuclear physics and medical physics	1,0% “radiation” + 0,8% “sample” + 0,7% “electron” + 0,7% “energy” + 0,7% “cell” + 0,7% “detector”
Topic 14	Fundamental particles and interactions	4,2% “particle” + 3,3% “energy” + 2,2% “electron” + 1,3% “mass” + 1,3% “quantum” + 1,1% “atom”
Topic 15	History and philosophy of physics	0,7% “book” + 0,5% “world” + 0,5% “scientist” + 0,5% “theory” + 0,5% “scientific” + 0,4% “idea”
Topic 16	Trends in physics education: course structures and career pathways	0,8% “pupil” + 0,7% “subject” + 0,6% “education” + 0,6% “project” + 0,4% “examination” + 0,4% “unit”
Topic 17	Programs, texts, and teaching strategies	1,1% “class” + 1,0% “program” + 1,0% “highschool” + 0,7% “college” + 0,7% “lab” + 0,7% “text”
Topic 18	Demonstrations and apparatus in physics teaching	3,0% “fig” + 1,2% “apparatus” + 0,8% “length” + 0,8% “demonstration” + 0,8% “cm” + 0,7% “spring”
Topic 19	Data acquisition and measurement in physics education	2,5% “data” + 1,7% “measurement” + 1,1% “graph” + 1,0% “sensor” + 0,9% “model” + 0,7% “experimental”
Topic 20	Innovative learning strategies in physics education	1,8% “learn” + 1,0% “activity” + 1,0% “question” + 1,0% “concept” + 0,9% “group” + 0,9% “research”

each topic (summing percent contributions from each article in each year), offering insight into the overall volume of research output.

The first 14 discovered topics are directly related to physics content, covering key areas such as Newtonian mechanics, waves and sound, electromagnetism, thermodynamics, fluid mechanics, optics, and nuclear physics.

These topics reflect the foundational principles and applied aspects of physics, serving as essential components of both high school and university-level instruction. For instance, the Newtonian mechanics and Applied mechanics topics explore motion, forces, and energy. Example articles from these topics include “*What is Centrifugal Force?*” (TPT, 1980) [34], which examines how centrifugal force is

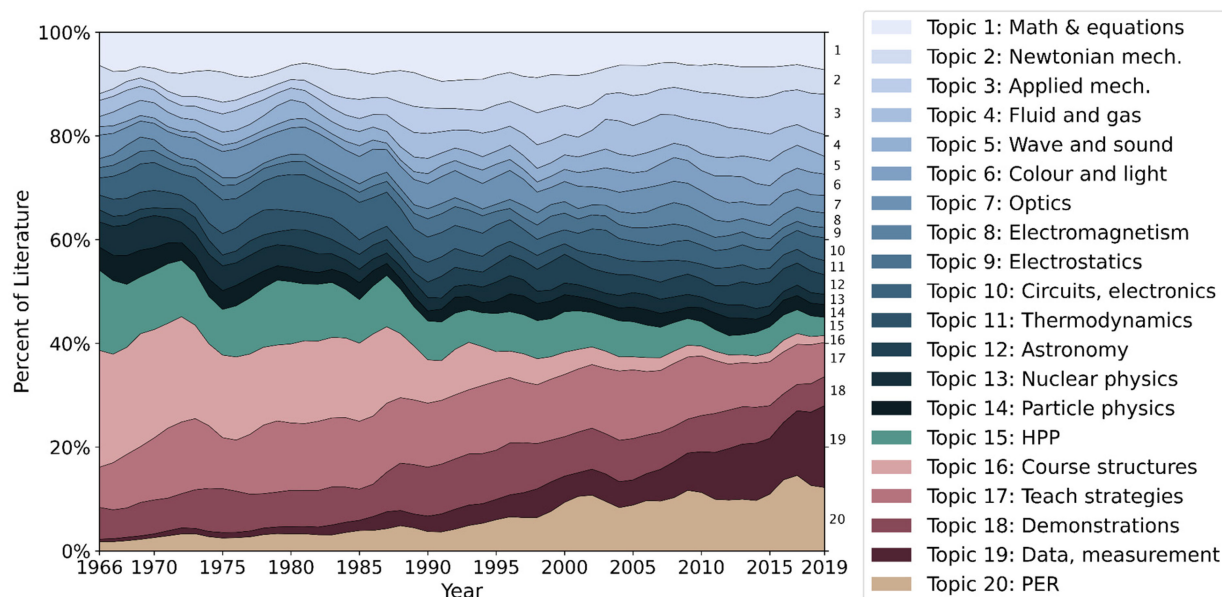


FIG. 1. Stacked area plot displaying the normalized prevalence of 20 topics in *Physics Education* and *The Physics Teacher* from 1966 to 2019 (with a three-year rolling window). The plot illustrates the percentage prominence of each topic over time, with content-based topics (blue) at the top, followed by History and philosophy of physics (green), teaching-focused topics (pink), and the PER-focused topic (brown) at the bottom.

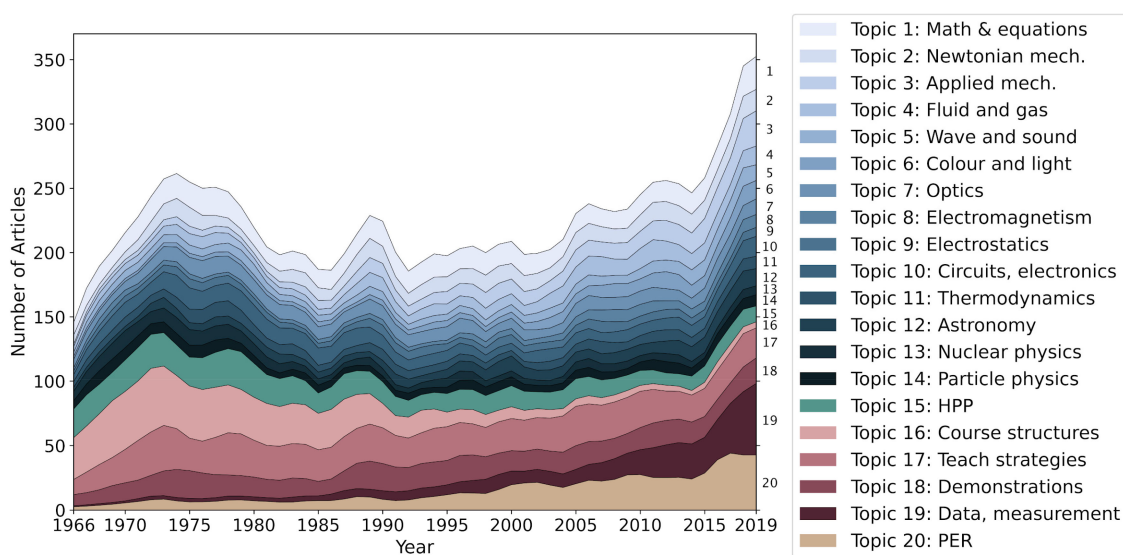


FIG. 2. Stacked area plot displaying the un-normalized prevalence of 20 topics in *Physics Education* and *The Physics Teacher* from 1966 to 2019 (with a three-year rolling window). Each topic width represents the number of articles on that topic per year, calculated as the sum of the percent contributions across all articles. Content-based topics (blue) are at the top, followed by the History and philosophy of physics topic (green), teaching-focused topics (pink), and the PER-focused topic (brown) at the bottom.

presented in introductory physics textbooks and its diverse interpretations, and “When equal masses don’t balance” (PE, 2004) [35], an article that explains the function of a modified Atwood’s machine in an accelerated frame of reference without using calculus while emphasizing the importance of selecting appropriate systems for free-body diagrams.

Meanwhile, articles featuring the *Circuits and electronics* topic focus on electrical components and their applications, with studies such as “Using a Multimeter to Study an RC Circuit” (TPT, 1995) [36] and “Analogue-to-Digital Conversion Made Easy” (PE, 1992) [37], demonstrating practical techniques for circuit analysis and digital signal processing. Articles within the *Astronomy* topic delve into

celestial mechanics and observational techniques, with studies like “Solar and Lunar Demonstrators” (PE, 2009) [38], providing hands-on models for teaching astronomical phenomena, and “Simulating the Phases of the Moon Shortly After Its Formation” (TPT, 2014) [39], offering insights into lunar evolution. At the smallest scale, articles on *Fundamental particles and interactions* address the subatomic structure of matter, as explored in “The Standard Model” (PE, 1992) [40], which outlines the framework of particle physics, and “A Temporary Organization of the Subatomic Particles” (TPT, 1975) [41], which examines early classifications of elementary particles.

In summary, we discovered that many articles are primarily related to topics that encompass core physics content areas: mathematical foundations (topic 1), mechanics (topics 2–4), waves and optics (topics 5–7), electricity and magnetism (topics 8–10), thermodynamics (topic 11), astronomy (Topic 12), and modern physics, including nuclear and particle physics (topics 13 and 14). These content-focused articles have played a crucial role in the journals by serving as a forum for physics teachers to engage with disciplinary knowledge relevant to their teaching practice. The journals provide space for discussions on high-school-level physics content, often debating finer conceptual points, clarifying common misconceptions, and offering alternative explanations for various phenomena.

Beyond core physics content, *Topic 15, History and philosophy of physics*, explores the lives and contributions of key scientists (e.g., “Albert Einstein: His Life”, 1979—PE [42]), the evolution of scientific thought (“Assimilation and Development in Arab Scientific Thought”, 1966—TPT [43]), and the role of historical texts (“Early Science Books and Their Women Translators”, 1998—TPT [44]). It also examines the intersection of physics with broader cultural and philosophical themes (“A non-believer looks at physics”, 1987—PE [45]). Some articles focus on ethical and social issues in science, related to pivotal experiments in the history of physics (“Where credit is due The Leaning Tower of Pisa Experiment”, 1972—TPT [46]). This topic highlights how historical narratives and philosophical reflections shape our understanding of physics today.

The next group of topics, 16–19, emphasizes physics teaching in the form of pedagogical frameworks and methodologies. The individual topics focus on various aspects of physics teaching, including course structures, career pathways, curriculum design, laboratory instruction, demonstrations, data acquisition, and assessment techniques.

Topic 16, *Trends in physics education: course structures and career pathways*, focuses on innovations in the organization and development of physics education courses, examining their relationship with societal and organizational needs, such as careers, occupations, and specializations. The 15 articles with the highest percentage

of this topic are all published in the *Physics Education* journal. Example publications include “Occupation of Successful Candidates in 1969 Graduateship Examination of The Institute of Physics” (1972) [47], which analyzes employment patterns of physics graduates, offering insights into professional trajectories. Alternatively, “Physics in the polytechnics” (1980) [48] examines the role of polytechnic institutions in physics education. Similarly, “The Higher National Diploma in Applied Physics” (1969) [49] discusses the development of specialized physics programs and their impact on students’ technical expertise. These studies highlight the evolution of physics education systems and their alignment with industry and academic demands. As visible in Fig. 2, the number of publications under this topic progressively decreased over time, mostly disappearing around the 1990s.

Topic 17, *Programs, texts, and teaching strategies*, most commonly appeared in articles from *The Physics Teacher*, addresses considerations in school programs, textbook selection, teaching strategies, and assessment methods. Example articles include “Student Selection of the Textbook for an Introductory Physics Course” (2007) [50] and “How do you select your physics textbook?” (1989) [51], which explores how students and instructors navigate the choice of instructional materials, reflecting ongoing discussions about the role of textbooks in physics learning. Similarly, “Update on the status of the one-year, non-calculus physics course” (1994) [52] reviews the structure and evolution of introductory physics courses, while “Retests: a better method of test corrections” (2011) [53] discusses alternative assessment strategies aimed at improving student understanding through iterative feedback.

Topic 18, *Demonstrations and apparatus in physics teaching*, highlights the development and adaptation of experimental tools to enhance physics instruction. In particular, the topic focuses on hands-on demonstrations designed to make abstract concepts more tangible. Most of the articles that are described by this topic are published in *The Physics Teacher*. For instance, “Rotational motion demonstrator” (1988) [54] presents an apparatus to illustrate angular momentum and rotational dynamics in an engaging way, while “The Iowa wave machines” (2010) [55] explores an accessible method for visualizing wave propagation and interference patterns. Similarly, “Apparatus for Measuring Young’s Modulus” (2003) [56] provides a straightforward setup for students to experimentally determine the elastic properties of materials. These studies emphasize the crucial role of interactive demonstrations in fostering conceptual understanding and student engagement in physics learning.

Topic 19, *Data acquisition and measurement in physics education*, focuses on the integration of technology and computational tools in experimental physics instruction. This topic appeared in both *The Physics Teacher* and

Physics Education in articles that highlight innovative approaches to data collection and analysis. For instance, “Modeling Physics with Easy Java Simulations” (TPT, 2007) [57] explores the use of computational modeling to visualize and simulate physical phenomena, enhancing students’ ability to engage with abstract concepts. Similarly, “An Arduino Experiment to Study Free Fall at Schools” (PE, 2018) [58] demonstrates how microcontroller-based experiments can provide accessible, high-precision measurements, fostering a deeper understanding of motion and acceleration. These studies underscore the growing role of digital tools in modern physics education and computational physics, enabling more interactive and data-driven learning experiences.

The final topic, topic 20, focuses on *Innovative learning strategies in physics education*, representing the intersection between PER and classroom practice. This topic focuses primarily on physics learning, rather than teaching, and examines how research-based insights become crucial to improve physics learning. Results from PER, such as active learning and student-centered instruction, are advocated to be integrated into teaching to enhance student engagement and learning outcomes. Articles well represented by this topic are “Using the Force Concept Inventory to Monitor Student Learning and to Plan Teaching” (PE, 2002) [59], which explores how students’ outcomes in concept inventories can inform instructional decisions, as well as “Learning from Mistakes: The Effect of Students’ Written Self-Diagnoses on Subsequent Problem Solving” (TPT, 2016) [60], which examines the role of self-reflection in improving problem-solving skills. Another example, which critically analyzes the impact of textbooks on students’ ability to think creatively in physics, is “Physics textbooks: do they promote or inhibit students’ creative thinking?” (PE, 2015) [61].

These discovered topics provide a comprehensive view of the evolving landscape of physics education, reflecting both the interests of the journals and the broader community in key disciplinary content and instructional strategies that shape the teaching and learning of physics.

Furthermore, we found that very few articles are primarily characterized by a single topic. In fact, only 2.8% of the articles are predominantly represented by a topic (with a weight over 75%). The remaining articles typically blend multiple themes. For example, content-based articles may address practical aspects, such as designing effective demonstrations or improving laboratory experiments, thereby reinforcing the connection between theoretical knowledge and hands-on learning.

B. Major trends in the physics education literature

In this section, we highlight three key periods of increased publication activity, each marking a significant phase in the evolution of physics education.

1. Initial surge in publications (1966–1973)

As illustrated in Fig. 2, the annual number of publications increased from approximately 150 to around 250, indicating a consistent upward trend. This can be attributed to the natural growth in the number of publications as both journals became more established and gained recognition in the field. Their increasing reputation likely contributed to a steady rise in submissions over time.

2. Hands-on learning, educational reform, and the rise of PER (1985–1990)

During this period, we observe a notable increase in three specific topics. In particular, topic 18 sees a significant rise in publications about demonstrations and teaching equipment. Based on the historical context, this surge likely reflects a growing emphasis on fostering conceptual understanding. Laboratory demonstrations provided a tangible way to explore physics concepts, an approach further enhanced by the emergence of innovative technological applications during this period. Several articles exemplify this trend: “A Standing Wave Simulator” (1989) [62] introduced a tool for visualizing wave behavior, while “An Interactive Soap Film Apparatus” (1988) [63] explored novel methods for demonstrating surface tension effects. Additionally, “The Suitcase Gyroscope. An Angular Momentum Device” (1987) [64] provided educators with a practical tool to illustrate rotational dynamics, reinforcing the movement toward accessible and impactful teaching demonstrations.

Additionally, during this same time period, topic 20 (related to PER) begins to emerge. There were increasing concerns about the effectiveness of physics instruction and the challenges students faced in conceptual understanding. This period coincided with the establishment of PER as area of research, which sought to address these challenges by investigating how students learn physics and developing evidence-based strategies to improve teaching practices. For instance, one article from this period is “An Investigation of Exemplary Physics Teaching” [65], which highlighted systemic issues in physics education, particularly the dominance of rote memorization over inquiry-based learning. The study echoed broader educational reform movements in the United States and the United Kingdom, which raised alarms about declining student engagement, shortages of qualified physics teachers, and the lack of real-world relevance in physics curricula. At the same time, researchers and educators were becoming increasingly aware of specific learning difficulties in physics. For example, in “Student Misconceptions in Mechanics: An International Problem” [66], there is a description of how students persistently held misconceptions about fundamental physics concepts—such as the belief that heavier objects fall faster than lighter ones—even after formal instruction. This article was emblematic of the emerging research

paradigm of studying student misconceptions, which became a central focus of PER during this period.

Furthermore, we observe the initial rise of topic 19, which reflects the increasing role of technology in physics education, particularly in data collection and analysis. The late 1980s saw the integration of computers into experimental physics teaching, enabling more precise measurements and real-time data visualization [19]. Articles like *Computer Use for the High School Physics Teacher: Using Available Tool Software* [67] highlight efforts to incorporate computational tools into physics instruction, making data acquisition more efficient. This trend continued into the early 1990s, as seen in *Graphing with Computers in the Physics Lab* [68], which demonstrated how computer-based graphing tools could enhance students' understanding of experimental results.

3. Technological integration and PER expansion (2000–2020)

The most significant increase in publications during this period is driven by the growing prominence of topics 19 and 20. The first focuses on computational physics and the integration of technology in physics teaching, while the second focuses on the influence of PER findings in the teaching activity.

As shown in Fig. 3, publications on topic 19 nearly doubled between 2010 and 2020, with a cumulative threefold increase from 2005 to 2020 (Fig. 1). Similarly, publications on topic 20, which reflect the growing impact of PER findings on instructional methods and educational policies, began rising in the 1990s and doubled between 2000 and 2020.

Notably, 2005 marked the inception of *Physical Review Special Topics—Physics Education Research* (PRST-PER),

later renamed *Physical Review—Physics Education Research* (PRPER). Therefore, this period represents a turning point for the American PER community, as it experienced rapid growth and became an influential field within physics education. The rise of PRPER likely played a direct role in increasing the prevalence of PER-based articles in *The Physics Teacher* (TPT), as many of these publications build on results first published in PRPER.

In these years, multiple factors collectively solidified PER's credibility and impact, fueling its rapid growth [69]. For example, the growing legitimacy within the physics community, such as institutions like the American Physical Society (APS), formally recognized it as a subfield, and tenure-track positions became more available. Additionally, influential assessment tools like the FCI revealed widespread student misconceptions, driving a demand for research-based instructional reforms. Moreover, the expansion of professional development workshops and faculty training programs further disseminated PER findings, while the field's theoretical foundations were strengthened through interdisciplinary influences from cognitive science and learning theory.

At the same time, there was a surge in research exploring ways to integrate technology into physics education. This growth was driven by the increasing availability and affordability of computing tools (such as PCs, laptops, smartphones, tablets, sensors, and microcomputers) over the past 10 to 15 years. As these technologies became more accessible, the physics teaching community actively explored their potential to enhance classroom instruction.

Concurrently, the expansion of PER research likely contributed to the growing emphasis on learning strategies, instructional reforms, and the broader integration of research-based teaching practices in physics education.

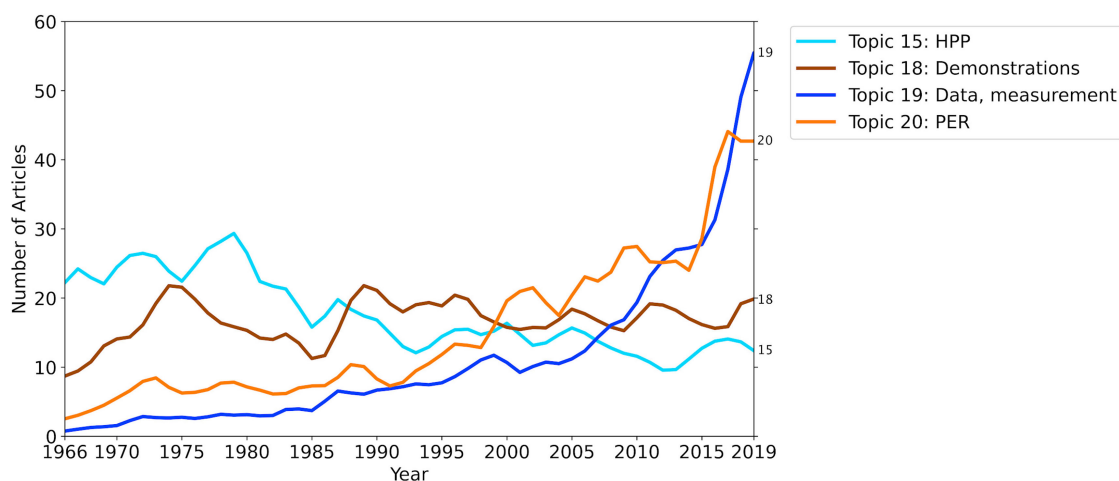


FIG. 3. Plot displaying the un-normalized prevalence of specific topics in *Physics Education* and *The Physics Teacher* from 1966 to 2019 (with a three-year rolling window), that are Topic 15 about History and philosophy of physics (light blue), Topic 18 about demonstrations and apparatus (brown), Topic 19 about data and measurement (blue), and Topic 20 on PER (orange). Each topic width represents the number of articles on that topic per year, calculated as the sum of the percent contributions across all articles.

TABLE III. Key trends in physics teaching and publications (1966–2020).

Period	Focus	Exemplar articles	Historical context
1960s–1970s	Curriculum development	- <i>The higher national diploma in applied physics (1969)</i> - <i>Occupation of successful candidates in the 1969 graduateship examination of the Institute of Physics (1972)</i> - <i>High school physics curriculum development in the Philippines (1972)</i> - <i>The secondary school curriculum and science education (1973)</i> - <i>Physics courses at Loughborough (1978)</i> - <i>Career-oriented pre-technical physics curriculum in San Diego (1979)</i>	The Cold War and the Space Race drove investments in science education, leading to curriculum reforms such as the PSSC (Physical Science Study Committee) and Nuffield Physics.
1970s–1990s	Pedagogical strategies	- <i>Improving high school physics teacher preparation (1975) [70]</i> - <i>Teaching physics: A human endeavor—interview IV (1977) [71]</i> - <i>Thinking, reasoning and understanding in introductory physics courses (1981) [72]</i> - <i>Optics of the rear-view mirror: A laboratory experiment (1986) [73]</i> - <i>How do you select your physics textbook? (1989) [74]</i> - <i>Developing problem-solving thinking in physics education—experience from Papua New Guinea (1989) [75]</i> - <i>Removing preconceptions with a “learning cycle” (1995) [76]</i>	The rise of constructivist learning theories (e.g., Piaget, Vygotsky) emphasized active learning, influencing how physics was taught.
2000s–2010s	PER and computational physics influence	- <i>Using the Force Concept Inventory to monitor student learning and to plan teaching (2002)</i> - <i>Learning from mistakes: The effect of students’ written self-diagnoses on subsequent problem-solving (2016)</i> - <i>Teaching physics using PhET simulations (2010) [77]</i> - <i>Understanding resonance graphs using Easy Java Simulations (EJS) and why we use EJS (2015) [78]</i>	The spread of Physics Education Research (PER) led to data-driven, evidence-based teaching strategies, such as active learning, peer instruction, and computational modeling.

To organize and illustrate representative literature from our review corresponding to the key interests in physics teaching across the periods described above, we created Table III. Building on this overview, Table IV focuses specifically on laboratory practices, illustrating how approaches in physics education evolved between the 1980s and 2010s, with particular attention to the influence of technological advancements.

C. The importance of physics content

We found that a significant number of topics are related to core physics content. Throughout the entire period covered by the two journals, these content-based topics have represented a substantial portion of published articles. The proportion of articles focused on physics content has steadily increased, from approximately 45% of the total publications in 1966 to over 50% by the beginning of

TABLE IV. Evolution of laboratory approaches: 1980 vs 2010.

Period	Main characteristics	Exemplar articles	Technologies and methods
1980s	Traditional approach with analog instruments and mechanical demonstrations. Focus on hands-on experiments with standard equipment.	- <i>Rotational motion demonstrator (1988)</i> - <i>The suitcase gyroscope. An angular momentum device (1987)</i>	Use of simple tools such as dynamometers, pendulums, and basic circuits to demonstrate physical principles. Measurements were often taken manually.
2010s	Integration of digital technologies and simulations. Focus on interactive experiments and real-time data analysis.	- <i>Modeling physics with easy Java simulations (2007)</i> - <i>An Arduino experiment to study free fall at schools (2018)</i>	Introduction of digital sensors, Arduino, computer simulations, and data analysis software for more sophisticated and accessible experiments.

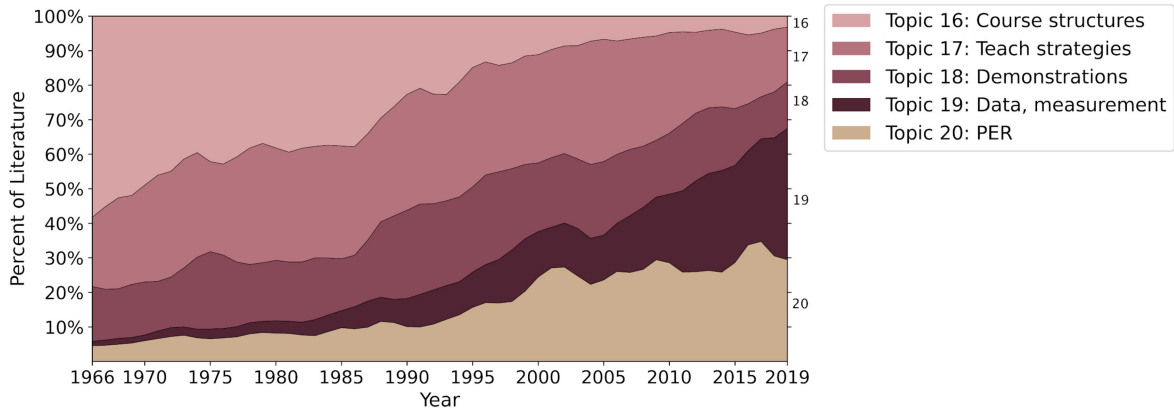


FIG. 4. Stacked area plot showing the normalized prevalence of topics 16 to 20 in *Physics Education* and *The Physics Teacher* from 1966 to 2019 (with a three-year rolling window). This plot illustrates the percentage prominence of each topic over time, highlighting the shift from teaching-focused topics (16–18, pink) to measurement and data (topic 19, purple) and learning-focused topics (topic 20, brown).

2020 (Fig. 1). This upward trend highlights the ongoing prominence of physics content in the literature over time.

While there has been variation in the level of interest in specific topics, with some seeing more attention than others, physics content has remained a central theme. It is important to note, however, that many articles focused on teaching or learning also include substantial physics content, making it challenging to isolate purely content-based articles.

To better understand this distribution, we analyzed the proportion of articles that are predominantly content-focused, finding 118 articles. This means that only 0.95% of all publications can be categorized as purely content-focused, defined as having more than 75% of their topics related to core physics content. Additionally, a small portion of publications (0.61%) has a 50% content focus and at least 25% of topics related to teaching, measurement, or PER (topics 18, 19, or 20), reflecting a mixed approach that integrates teaching or learning with significant physics content. Additionally, another small portion of publications (0.61%) have a 50% content focus and at least 25% of topics related to teaching, measurement, or PER (topics 18, 19, or 20), reflecting a mixed approach that integrates teaching or learning with significant physics content. This highlights that the majority of articles in these journals tend to combine physics content with smaller percentages of many other topics.

D. Shift from teaching to learning

To better understand how physics education has evolved, we exclude content-based topics (topics 1–14) and topic 15, which covers the history and philosophy of physics. This allows us to focus on the development of the remaining topics and uncover broader trends in the field.

When these topics are removed, the normalized distribution of the remaining ones reveals a clear pattern.

As shown in Fig. 4, what remains are the education-related topics (highlighted in pink), which primarily explore teaching practices, along with Topic 20, which emphasizes the integration of PER findings into classroom instruction. Over time, a noticeable shift emerges: The literature moves away from focusing solely on instructional methods and toward a deeper emphasis on student learning and the impact of research-based teaching strategies.

Specifically, in the 1970s, the predominant focus was on topics such as course structures and career pathways (topic 16), teaching strategies and programs (topic 17), and demonstrations and apparatus in physics education (topic 18). However, by the 1990s and extending into the 2020s, the emphasis shifted toward the integration of data acquisition and measurement in physics education (topic 19) and innovative learning strategies in physics education (topic 20).

This shift is evident not only in the number of publications specifically on these five topics, but also in the evolving focus of content-based articles. For example, the article *Optics of the Rear-View Mirror* (1986) [73] prioritizes clear content delivery and practical demonstrations for teachers, aiming to improve instruction rather than explore student learning processes. In contrast, a more recent article, *The Image Between the Lenses: Activities with a Telescope and a Microscope* (2003) [79], reflects a later shift toward PER-influenced, student-centered learning by directly addressing students' difficulties in understanding image formation and encouraging inquiry-based exploration. Rather than simply explaining optical principles, this article designs hands-on activities that help students *discover* key concepts, such as the existence of an intermediate real image in telescopes and microscopes.

These articles exemplify the broader transition that gained momentum around 1995, as PER began to influence physics education more strongly. From the mid-1990s onward, both journals increasingly emphasized a research-driven

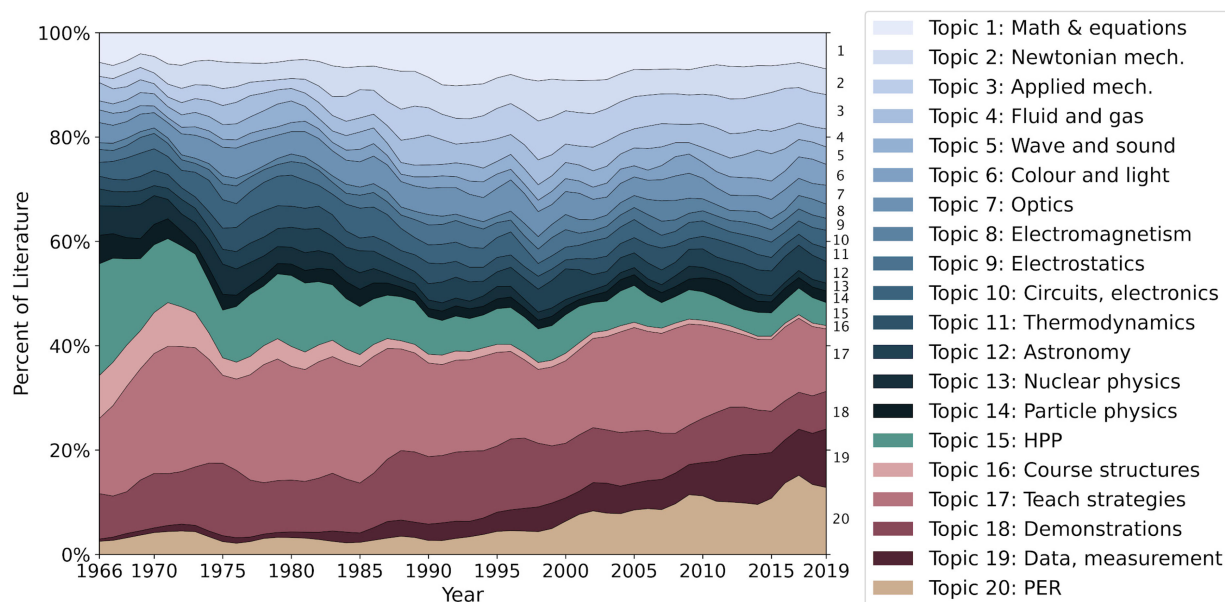


FIG. 5. Stacked area plot displaying the normalized prevalence of 20 topics in *The Physics Teacher* from 1966 to 2019 (with a three-year rolling window). The plot illustrates the percentage prominence of each topic over time, with content-based topics (blue) at the top, followed by History and philosophy of physics (green), teaching-focused topics (pink), and the PER-focused topic (brown) at the bottom.

understanding of how students learn physics, sparking new instructional approaches rooted in cognitive science and active learning methodologies.

E. Comparison of the two journals

In this section, we present the quantitative analysis of topic prevalence in *The Physics Teacher* and *Physics Education*. By grouping the results of the inductive LDA analysis by journal and examining topics' evolution over time, we compare their thematic focuses.

The stacked area plots in Figs. 5 and 6 illustrate the normalized topic trends in each journal from 1966 to 2019, while Figs. 7 and 8 present the un-normalized topic prevalence, showing the number of articles dedicated to each topic per year.

Starting with *The Physics Teacher* (Fig. 5), a balanced distribution between content-related topics and those centered on teaching practices and strategies is observed. In its early years, the journal gave emphasis on the History and philosophy of physics, a focus that, while still present, has gradually decreased over time. Nevertheless, this early emphasis on the broader context of physics education remains a distinctive feature of TPT.

Since the 1990s, topic 19, which relates to data acquisition and measurement, has gained prominence, reflecting technological advancements in physics education. Around 2000, the prominence of topic 18, which focuses on laboratory apparatus, began to decline, making way for topic 19. This shift suggests an evolution in the journal's focus from traditional laboratory instruments

to a hybrid approach, incorporating modern data acquisition techniques.

Overall, *TPT* has exhibited relative thematic stability, with a few notable shifts, such as the increasing emphasis on PER and educational technology.

In contrast, as for *Physics Education*, Fig. 6 reveals a more pronounced evolution in its thematic focus. Initially, from the 1960s to the 1980s, the journal primarily emphasized course structures and curricula. This focus may be attributed to the diversity of educational systems across Europe, where curricula and pathways vary significantly. In contrast, the United States' more standardized educational system may explain why *TPT* placed less emphasis on curricula and more on general pedagogical strategies. This distinction may warrant further exploration of articles from *PE* published between 1970 and 1985 to understand more about the specific curricula-related content.

A significant shift occurred in the mid-1990s when *PE* transitioned from curricula-focused discussions to a greater emphasis on content and pedagogy. By the early 2000s, articles on PER increased substantially, continuing to rise throughout the 2010s. This shift paralleled a growing interest in educational technology, aligning with broader trends in physics education. During this period, *PE* also strengthened its focus on content-based articles, which became increasingly prominent as the pedagogical discussions expanded.

Although *PE* has maintained some interest in the *History and Philosophy of Physics*, this focus has been notably weaker compared to *TPT*, with fewer dedicated articles. Instead, *PE* has increasingly emphasized content-oriented

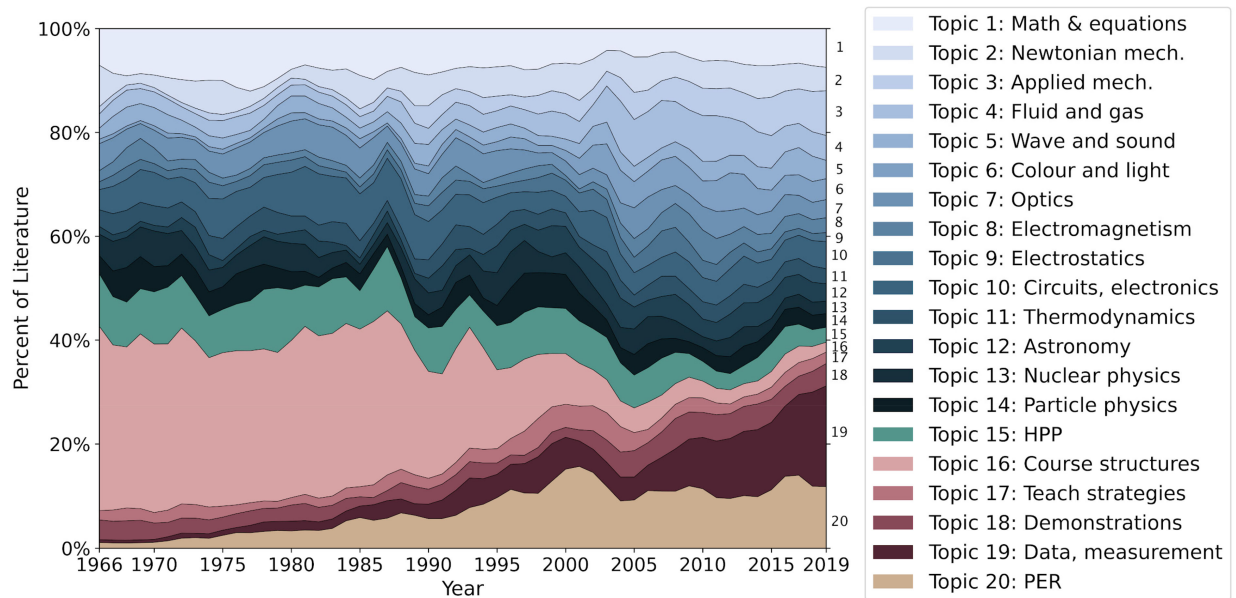


FIG. 6. Stacked area plot displaying the normalized prevalence of 20 topics in *Physics Education* from 1966 to 2019 (with a three-year rolling window). The plot illustrates the percentage prominence of each topic over time, with content-based topics (blue) at the top, followed by History and philosophy of physics (green), teaching-focused topics (pink), and the PER-focused topic (brown) at the bottom.

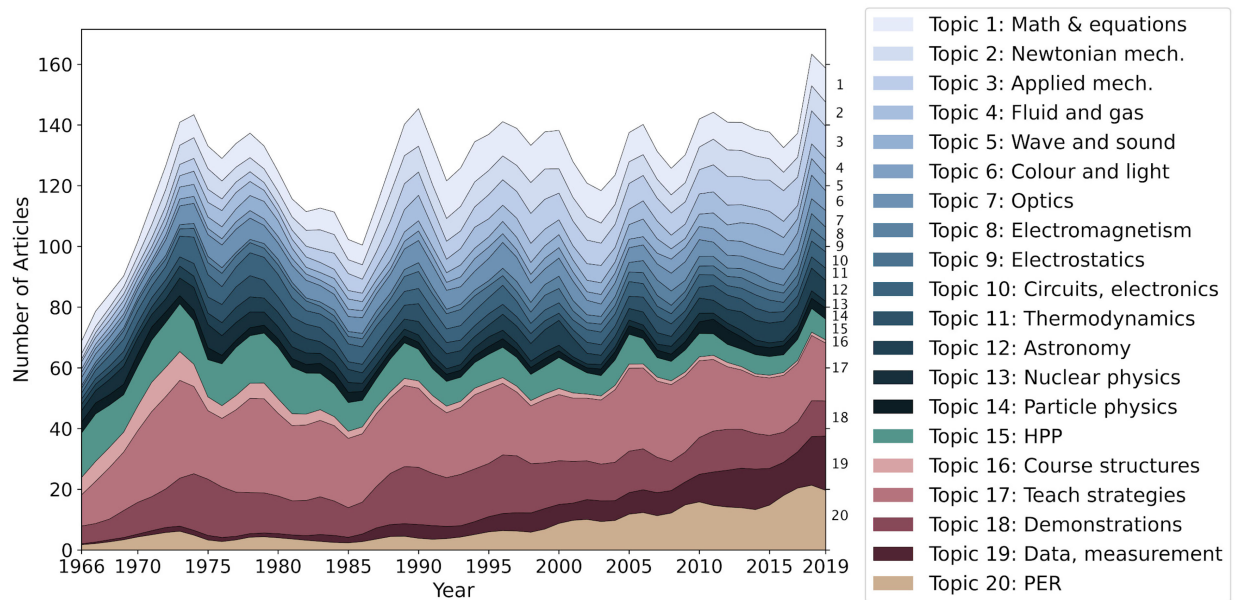


FIG. 7. Stacked area plot displaying the un-normalized prevalence of 20 topics in *The Physics Teacher* from 1966 to 2019 (with a three-year rolling window). Each topic width represents the number of articles on that topic per year, calculated as the sum of the percent contributions across all articles. Content-based topics (blue) are at the top, followed by the History and philosophy of physics topic (green), teaching-focused topics (pink), and the PER-focused topic (brown) at the bottom.

articles, likely responding to the growing demand for pedagogical examples directly tied to physics content. Such articles often combine practical applications with deeper content discussions and teaching methodologies.

A key distinction between the two journals is the timeline of their engagement with PER. PE demonstrated

an early interest in PER, beginning in the early 1990s, while TPT shifted toward PER later, in the late 1990s and early 2000s. This earlier focus in PE suggests a proactive engagement with the emerging field of PER, whereas TPT followed broader trends that gained momentum in the 2000s.

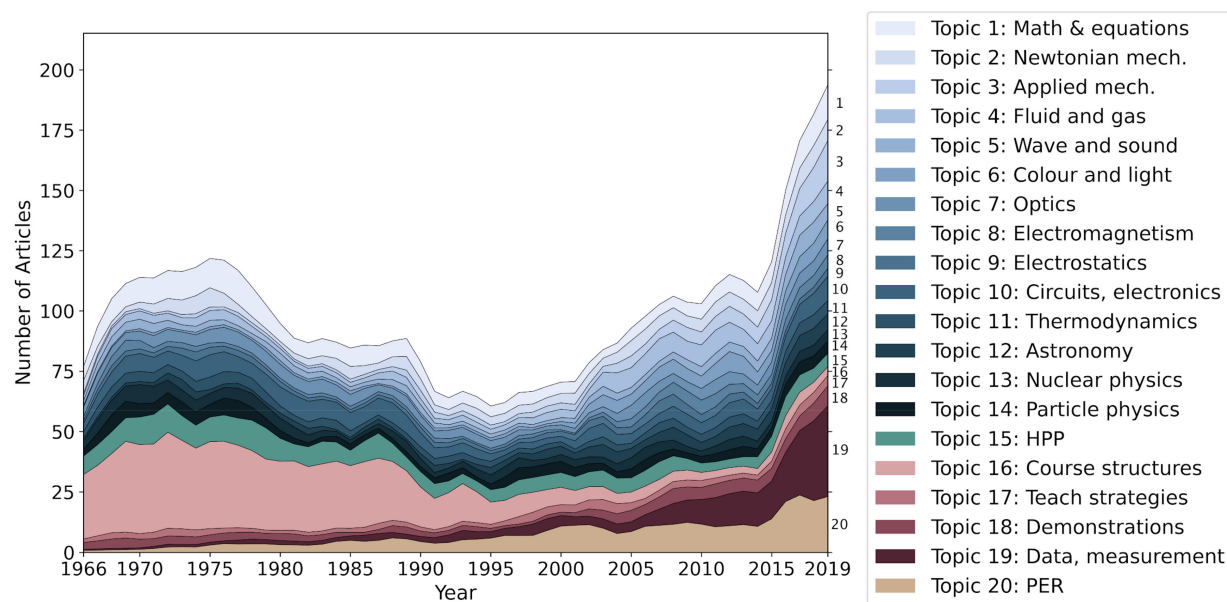


FIG. 8. Stacked area plot displaying the un-normalized prevalence of 20 topics in *Physics Education* from 1966 to 2019 (with a three-year rolling window). Each topic width represents the number of articles on that topic per year, calculated as the sum of the percent contributions across all articles. Content-based topics (blue) are at the top, followed by the History and philosophy of physics topic (green), teaching-focused topics (pink), and the PER-focused topic (brown) at the bottom.

Figures 7 and 8 provide additional insight into these trends. In TPT (Fig. 7), thematic focus has remained relatively stable, with a modest increase in PER and educational technology. Teaching strategies, textbooks, and demonstrations have persisted as central themes, underscoring TPT's long-standing commitment to practical aspects of physics teaching.

Conversely, PE (Fig. 8) exhibits a more dramatic shift. The journal's initial focus on curricula and educational pathways in the 1970s and 1980s gradually gave way to an emphasis on content, pedagogy, and PER by the mid-1990s. The sharp rise in PER-related articles, particularly from 2015 onward, signals a major directional change, aligning with broader transformations in physics education research and practice.

In summary, the analysis highlights key distinctions in the thematic focus of *The Physics Teacher* and *Physics Education*. TPT has maintained a relatively stable balance between content and teaching-related topics, consistently emphasizing pedagogy, history, and philosophy while increasingly incorporating PER and educational technology. In contrast, PE underwent a more pronounced shift, moving away from curricula-focused discussions in the mid-1990s toward greater emphasis on content, pedagogy, and eventually PER and technology in the 2000s and beyond.

VI. DISCUSSION

By analyzing the topics covered in *The Physics Teacher* and *Physics Education* over more than five decades,

we have identified key themes, their evolution, and the distinct roles these journals have played in shaping physics education discourse. These topics can be grouped into distinct thematic categories, reflecting the evolving priorities and interests in physics education over time.

Content-based topics, which have remained consistently present throughout their histories, form a foundational pillar of the literature in both journals. These topics focus on core physics concepts and their instructional representation, serving as a key resource for educators seeking content-specific guidance.

A second major category encompasses *teaching-focused topics*, including discussions on course structures, pedagogical strategies, laboratory activities, and demonstrations. These themes highlight the journals' role in supporting instructors by providing instructional material and methods to enhance the study of physics, and have been present in both journals from their inception until the present day.

Another noteworthy topic emerges from *Physics Education Research* (PER), which has contributed innovative learning strategies informed by empirical studies on how students engage with physics concepts. The increasing trend of this topic underscores a transition toward research-informed teaching methodologies aimed at improving student learning outcomes.

Finally, we have identified a distinct topic related to *historical and philosophical aspects of physics*, which played a prominent role in the early years of both journals. These discussions contextualized physics education within a broader cultural and scientific narrative, emphasizing

the development of the discipline and its philosophical implications.

Building on the historical reconstruction presented in the literature review (Sec. II A), the Cold War era was marked by significant efforts in both North America and Europe to enhance physics education. This trend is evident in our findings and helps account for the substantial increase in publications from the establishment of both journals until the early 1970s. Throughout the period analyzed, *The Physics Teacher* and *Physics Education* consistently prioritized physics content, addressing a wide range of topics.

Additionally, both journals played a crucial role in providing resources and support for educators, a defining characteristic from the 1970s through the late 20th century. As for European physics education, historically, it was shaped by multiple influences and movements. Our analysis reflects this dynamic by highlighting how *Physics Education* dedicated space to discussions on curriculum development, social aspects such as career pathways, and multidisciplinary connections, particularly with engineering. In contrast, *The Physics Teacher* focused more on teaching methodologies and pedagogical tools. This focus may stem from the relatively homogeneous structure of the North American educational system or reflect a deliberate editorial choice by the journal.

Over the past 30 years, physics education has been profoundly shaped by two key developments: the rise of computational tools and the increasing influence of PER on instructional practices. The 1990s marked a turning point, as advances in technology led to the growing use of software tools, sensors, and data analysis techniques in physics instruction. Our analysis reflects this shift, showing the emergence of topics related to measurement and computation within the journals. This transformation highlights a broader movement toward evidence-based teaching, where technological advancements are not only enhancing laboratory experiences but also reshaping pedagogical strategies to prioritize student engagement and conceptual understanding.

Through our thematic analysis, we quantify a significant shift in both journals from a teaching-centered focus, emphasizing course structures, instructional strategies, and laboratory apparatus (as seen in topics 16–18, which address teaching strategies, physics careers, and traditional laboratory setups), to a more student-centered approach. We hypothesize that this transformation has been driven by the growing influence of PER and the integration of educational technologies, both of which have played a crucial role in advancing active learning and evidence-based instructional practices. This shift reflects a broader evolution in physics education, where student engagement, conceptual understanding, and data-driven pedagogical strategies are increasingly prioritized over traditional models of instruction.

This study offers a novel contribution by systematically analyzing the thematic evolution of *The Physics Teacher*

and *Physics Education* over an extended period. By examining these journals collectively and individually, we provide a comprehensive overview of the major themes in physics education while also identifying their distinctive areas of focus.

Our findings offer valuable insights into the historical development of the field and build on prior scholarship, such as the work by Otero and Meltzer, by analyzing a much larger body of literature. While their research provides critical perspectives on specific aspects of physics education, our study extends these discussions over a longer timeframe, revealing broad trends that may be less visible in year-to-year analyses. However, our approach remains at a relatively coarse level, offering general insights rather than fine-grained historical narratives.

By placing our findings within the broader historical context of physics education, we highlight how teaching practices have evolved in response to pedagogical research and technological advancements. PER has played a crucial role in shifting the focus from teaching-centered to learning-centered methodologies, and our study reinforces this trajectory by demonstrating how these shifts unfold over longer time scales. Examining these trends over multiple decades enables us to identify significant transformations. For instance, the increasing role of computation and technology in physics education may not be as apparent in shorter term studies.

A. Limitations of this study

Our study has several limitations. First, the dataset primarily reflects published literature and does not necessarily capture actual physics teaching practices in classrooms. The journals analyzed serve as important forums for discourse, but the extent to which their content translates into widespread instructional change requires further investigation.

Second, our analysis is constrained by the methodological characteristics of LDA and the BoW representation [21]. While LDA is well understood and has been successfully applied to related corpora (see Sec. II C 2), it is important to clarify that the topics identified by the model do not necessarily correspond to the most “important” topics for understanding the evolution of physics teaching. LDA identifies frequent and coherent combinations of words that appear across the documents. In our dataset, composed of articles from physics teaching journals, it is reasonable that many topics relate to scientific content (14 out of 20), as words associated with mechanics, nuclear physics, and other content areas are frequent and easily clustered. However, six topics were clearly focused on other aspects of physics teaching, demonstrating that the model can capture meaningful information even for more subtle themes.

To achieve this result, we carefully curated the parameters for vocabulary creation, ensuring that important terms for physics education were included even if frequent or

general (e.g., “learn”, “question”, and activity”), balancing the model’s constraints with research questions–driven priorities. Moreover, by isolating noncontent topics (see Sec. V D), we deliberately focused on those topics that could inform us about classroom practices or interests beyond physics content. This strategy is crucial for observing significant shifts over time, including the move from teacher-centered to student-centered approaches, the increasing role of laboratories and simulations, and the influence of Physics Education Research and technological innovations.

Alternative NLP approaches can complement or extend these findings, particularly for detecting nuanced or multi-word expressions. Text embedding methods provide a novel way to represent and manipulate textual data, capturing semantic relationships beyond the limitations of traditional bag-of-words approaches [28]. Building on this, large language models represent a new class of models based on embeddings, capable of performing complex language tasks. The chapter by Wulff *et al.* [80] illustrates practical examples of applying these techniques in science education contexts, showing how they can be systematically used to analyze textual data. More generally, AI techniques can be integrated into qualitative analyses to identify meaningful themes; for example, computational grounded theory [81], applied in physics education research, combines human interpretive depth with computational scalability to enhance validity and reproducibility. Finally, thematic network analysis [82] provides a complementary approach for fully transparent and reproducible analysis, enabling the identification and inspection of thematic structures at multiple levels of granularity.

Third, our analysis is limited to two English-language journals. While other journals devoted to physics teaching exist in various countries, such as *Fra Fysikkens Verden* in Norway (published since 1962), *Fysikaktuellt* in Sweden, *Il Giornale di Fisica* in Italy (founded in 1956), and German journals like *Phydid A* and *Phydid B*, these publications are typically national in scope and published in their respective languages. In contrast, *Physics Education* provides a broader European perspective, as it is published by the Institute of Physics, an organization with an international membership base. This makes it a comparable counterpart to *The Physics Teacher*, which is associated with the American Association of Physics Teachers. The choice of these two journals was also driven by their long publication history, data availability, and comparability across decades.

Fourth, the use of *Physics Education* as a source for European physics education carries specific constraints. Although the journal is published in Europe, it has been historically UK-centered, especially during the early decades. We did not have data on the nationality of authors, nor did the journal website provide reports on this. To address this, we estimated institutional contributions of articles published on *Physics Education* for selected years

(1966, 1980, 2000, 2010, and 2019) using the OpenAlex dataset. Our analysis shows that early contributions were predominantly European, mostly from the United Kingdom, while, in 2000, approximately 65% came from Europe, 19% from North America, and 14% from Asia. In later years, the distribution reflected a broader international contribution: Europe ~53%, North America ~20%, Asia ~16%, and Oceania ~8%. The Python notebooks used for these calculations are included in the GitHub repository cited in the Data Availability Statement section. These results indicate that while the journal can reasonably represent a European perspective, especially in earlier decades, the last 20 years reflect a more international discourse that should be interpreted accordingly.

Finally, our study does not include the most recent developments in physics education, such as the impact of the COVID-19 pandemic and the integration of artificial intelligence in educational settings. Historical interpretations are constrained by the corpus and modeling decisions; a deeper engagement with primary sources would be necessary for a more detailed narrative.

Despite these limitations, our study provides a structured framework for understanding trends in physics education discourse and offers insights into the evolving practices of teaching physics.

VII. CONCLUSIONS

Over the past six decades, the literature published in *The Physics Teacher* and *Physics Education* has reflected and shaped the evolution of physics education, mirroring broader pedagogical and technological shifts. Although physics content has remained essential to physics education, laboratory activities have evolved, moving from traditional demonstrative apparatus toward more computational and software-based approaches, including interactive simulations and data-driven experimentation.

Our findings reveal a clear transition from a teaching-centered approach, focused on course structures, demonstrations, and instructional strategies, to a learning-centered paradigm. The growing influence of PER has played a key role in this shift, emphasizing student engagement, conceptual understanding, and evidence-based pedagogical practices. These trends underscore the dynamic nature of physics education as it continues to adapt to new research insights, technological advancements, and shifting educational priorities.

Looking ahead, this study opens the door to further research on the evolution of physics education discourse, both through expanded historical analyses and the application of more advanced computational methods. Future work could explore how emerging trends, such as artificial intelligence, online education, and the post-pandemic learning environment, are reshaping the field.

Moreover, as text-mining techniques and generative AI continue to evolve, they offer promising opportunities to

uncover deeper patterns in educational literature, generate novel insights, and assist in synthesizing large bodies of work. These tools have the potential to greatly enhance our understanding of how teaching practices and research agendas develop over time. By embracing these methods, physics education researchers can gain new perspectives on the discipline’s past, present, and future, enriching our knowledge of how physics is taught and learned worldwide.

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Computation of the University of Bologna and the Marco Polo project of the same university.

DATA AVAILABILITY

The code and the data that support the findings of this article are openly available. Specifically, the article metadata, topic weights, and the bag-of-words text representations (including bigrams) are publicly accessible via the Zenodo dataset [83] and the GitHub repository [84]. The original articles’ texts cannot be made publicly available due to copyright.

APPENDIX

The appendix table lists the 20 topics identified in the combined LDA analysis, along with the 15 most representative articles for each topic, and their corresponding year and journal of publication.

Article title	Year	Journal
Topic 1—Fundamental equations and mathematical principles in physics: 2,9% “equation” + 1,0% “constant” + 0,8% “unit” + 0,8% “mass” + 0,7% “term” + 0,6% “equal”		
Plane angle and pi as physical quantities	1973	PE
Graphical analysis of electric fields of dipoles and bipoles	2000	TPT
Back to the physics: Integration by Gauss	1998	TPT
The twin paradox	1985	PE
Electric field of a two-charge dipole: A graphical approach extended	2000	TPT
Gravitational force due to a sphere: A noncalculus calculation	2003	TPT
On the teaching of the electric dipole	2001	TPT
The estimation of errors ...	1966	PE
An alternative method for solving the elementary equation for damped oscillation (teaching)	1979	PE
A closer look at Fermat’s principle	1986	PE
Perverse symbolism	1989	PE
The physics of $\lim_{\theta \rightarrow 0} (\sin \theta)/\theta = 1$	2019	TPT
Moment of inertia by differentiation	2015	TPT
The vertical spring-mass system and its “equivalent”	1976	TPT
“Bad” vibes: The damped oscillator	1992	TPT
Topic 2—Newtonian Mechanics: 5,7% “force” + 2,4% “motion” + 1,9% “acceleration” + 1,9% “mass” +1,8% “object” + 1,7% “body”		
Acceleration =	1966	PE
What is centrifugal force?	1980	TPT
Drawing forces	1998	TPT
A very persistent mistake	2011	PE
Centrifugal force	1975	PE
“Apparent weight”: A concept that Is confusing and unnecessary	2010	TPT
NOTES: Right way up	1973	TPT
Centrifugal force	1973	PE
Do centrifugal forces exist?	1971	PE
Newton’s laws: A very persistent consistency	2012	PE
Physics that textbook writers usually get wrong: III. Forces and vectors	1992	TPT
The physics we want	1985	PE
When equal masses don’t balance	2004	PE
Muscle forces	1992	PE
Physics in a bouncing car	1984	TPT

(Table continued)

Article title	Year	Journal
Topic 3—Applied mechanics: 3,7% “ball” +2,2% “speed” +1,5% “velocity” +1,1% “collision” +1,0% “fall” +0,9% “motion”		
Spinning eggs and ballerinas	2013	PE
Enhancing the bounce of a ball	2010	TPT
Bounce of a perfectly elastic ball	2019	PE
Rolling motion of a ball spinning about a near-vertical axis	2012	TPT
Why do some balls spin faster than others when they bounce	2019	PE
Newton’s cradle in billiards and croquet	2016	PE
Behavior of a bouncing ball	2015	PE
Ball collision experiments	2015	PE
Elastic and inelastic collisions of a ball with a wood block	2017	TPT
Motion of a ball on a moving surface	2016	TPT
Surprising behavior of spinning tops and eggs on an inclined plane	2016	TPT
A spinning top for physics experiments	2019	PE
Precession of a spinning ball rolling down an inclined plane	2015	TPT
Why low bounce balls exhibit high rolling resistance	2015	PE
Static friction on a ball rolling down an incline	2018	PE
Topic 4—Fluid mechanics and gas laws: 4,6% “water” + 2,5% “pressure” + 2,2% “air” + 1,8% “liquid” + 1,4% “volume” + 1,1% “tube”		
The Cartesian diver, surface tension, and the Cheerios effect	2014	PE
Mariotte bottle with side openings	2006	TPT
Archimedes’ principle in action	2007	PE
The secret siphon	2011	PE
Filling or draining a water bottle with two holes	2016	PE
Simple buoyancy demonstrations using saltwater	1989	TPT
Easy test calculates air’s weight	2009	PE
Liquid nitrogen turns down the temperature on gas-law demos	2004	PE
Having fun with liquid nitrogen	2005	PE
Fizziology	2004	PE
Water barometer	1993	TPT
Siphonic concepts examined: A carbon dioxide gas siphon and siphons in vacuum	2011	PE
Rubber balloons, buoyancy, and the weight of air: A look inside	2009	PE
Physics trick gets students interested	2008	PE
Measuring liquid density using Archimedes’ principle	2006	PE
Topic 5—Waves and sound: 4,7% “frequency” + 3,6% “wave” + 3,1% “sound” + 1,4% “signal” + 1,0% “amplitude” + 0,8% “pulse”		
Using musical intervals to demonstrate superposition of waves and Fourier analysis	2013	PE
Another look at combination tones	2019	TPT
Fourier analysis of musical intervals	2008	TPT
Twenty-four tuba harmonics using a single pipe length	2017	PE
Amplitude, frequency, and timbre with the French horn	2018	PE
Experimenting with musical intervals	2003	PE
Acoustics of percussion instruments-part I	1976	TPT
Teaching resonance and harmonics with guitar and piano I	2014	TPT
Signal frequency spectra with audacity®	2015	TPT
Physics and psychophysics of high-fidelity sound	1979	TPT
Inharmonic spectra with a rock guitar effects pedal	2018	TPT
Complexity of pitch and timbre concepts	1998	PE
Mouthpiece and Bell effects on Trombone resonance	2014	TPT
Phase shifting and the beating of complex waves	2011	PE
Students dance longitudinal standing waves	2017	PE

(Table continued)

Article title	Year	Journal
Topic 6—Colour and light: 4,9% “light” + 1,8% “image” + 1,5% “colour” + 1,5% “color” + 1,2% “spectrum” + 1,1% “camera”		
Yellow: The magic color	2008	TPT
Demonstrating fluorescence with neon paper and plastic	2015	TPT
A photoshoot for food and drink: Camera “sees” more than you think	2004	PE
Yellow	1994	TPT
Observing colours and spectra produced by a digital projector	2007	PE
Color reproduction with a smartphone	2013	TPT
Optical experiments using mini-torches with red, green, and blue light emitting diodes	2007	PE
Fluorescence spectra of highlighter inks	2018	TPT
Color mixing with four prisms redux	2018	TPT
Low-cost experiments on infrared phenomena	2013	PE
Tricks with invisible light	2003	PE
Ultraviolet photography and insect vision	2019	TPT
Easy observation of infrared spectral lines	2012	PE
Confusing color concepts clarified	1999	TPT
“Can You See Me Now?” Using a favorite haunted physics laboratory project to teach color theory	2011	TPT
Topic 7—Optics: 2,6% “light” + 2,6% “image” + 2,1% “lens” + 1,5% “mirror” + 1,3% “object” + 1,3% “ray”		
Virtual mirrors	2010	TPT
Optics of the rear-view mirror: A laboratory experiment	1986	TPT
Multiple images in plane mirrors	1982	TPT
Comment on “From the pinhole camera to the shape of a lens: The camera-obscura reloaded”	2016	PE
Camera optics	1982	TPT
Polarisation experiments with a Fresnel biprism	1986	PE
A simple interferometer	1997	TPT
Curved mirrors	1995	PE
Demonstration of lens aberrations using a school laser	1976	PE
Optical transforms of the alphabet	1977	TPT
Lenses, pinholes, screens, and the eye	1991	TPT
Refractive index measurement with a ruler	1984	TPT
Reflections from a Fresnel lens	2005	PE
Reflections on handedness	2004	TPT
Covering lenses and covering images	1998	TPT
Topic 8—Electromagnetism and currents: 4,2% “magnet” + 3,0% “magneticfield” + 2,9% “field” + 2,9% “coil” + 2,4% “current” + 2,3% “magnetic”		
Universal “imaginary closed circuit method” and formula for determination of direction of induced emf/current	2011	PE
Demonstrate Lenz’s law with an aluminum ring	2008	PE
Demonstrating the Meissner effect and persistent current	2000	TPT
A simple demonstration of motional electromotive force	2012	PE
A new version of an old demonstration experiment using the Elihu Thomson jumping ring apparatus	2016	TPT
Thomson’s jumping ring over a long coil	2018	TPT
Interacting compasses	2009	TPT
A simple way to teach magnetic braking	2007	PE
Superconducting cylinders aid in an understanding of current induction	2004	PE
Using LEDs to demonstrate induced current	1992	PE
A pictorial approach to Lenz’s law	2018	TPT
Abstract concepts come to life	2008	PE
Motional mechanisms of homopolar motors and rollers	2009	TPT
Aluminum rod rolls in nonuniform magnetic field	2012	PE
Measuring Earth’s local magnetic field using a Helmholtz coil	2014	TPT

(Table continued)

Article title	Year	Journal
Topic 9—Electrostatics, and atmospheric physics: 2,2% “charge” + 1,6% “surface” + 0,9% “plate” + 0,7% “wind” + 0,7% “air” + 0,7% “area”		
Suppression of lightning by chaff seeding	1975	TPT
The THUNDERSTORM	1968	PE
Thermal patterns in the snow. Part II	1976	TPT
Exploration glaciology: Radar and Antarctic ice	2007	PE
Investigation of the airflow around a sail	1986	PE
Coalescence of raindrops in an electrostatic field	1999	TPT
A life of snow	1969	TPT
Thermal patterns in the snow, part I	1976	TPT
The lightning discharge	1976	TPT
Attraction or repulsion of a rod via electrical induction	2011	PE
Fire resistance of framed buildings	2002	PE
Demonstration of a Faraday cage using a metal leaf electroscope	2019	TPT
Physics: Clairvoyant of the Earth	1991	PE
Thermal patterns in the snow: Icicles as indicators of heat loss	2008	TPT
The physics of snow and avalanche phenomena	1980	TPT
Topic 10—Circuits and electronics: 2,4% “circuit” + 2,3% “voltage” + 2,0% “current” + 1,3% “resistance” + 0,8% “output” + 0,7% “power”		
Analogue-to-digital conversion made easy	1992	PE
Investigating the active region of transistor characteristics	1993	PE
A second step to TTL circuitry	1976	PE
Developing a four-channel oscilloscope multiplexer for displaying digital sounds	1991	PE
Microcomputer-controlled experiments	1982	PE
Arithmetic operations using TTL	1976	PE
A microcomputer interface for external circuit control	1983	PE
A simple voltage-to-frequency converter	1974	PE
Output resistance	1996	TPT
Cheap sensors for Pasco SW-500 interfaces	2003	PE
Demonstrating electrical principles using an	2001	PE
An elementary introduction to TTL	1975	PE
Using a multimeter to study an RC circuit	1995	TPT
Seeing rectifiers at work	2002	TPT
Electronic counter-timers for \$6.00 per digit	1977	TPT
Topic 11—Thermodynamics: 5,8% “temperature” + 4,5% “energy” + 2,4% “heat” + 1,1% “power” + 1,0% “cool” + 0,8% “water”		
Applications of refrigeration systems	1986	TPT
Some energy problem problems and solutions	1978	TPT
Power generation: Nuclear, oil, coal	2005	TPT
Removing the mystery of entropy and thermodynamics—Part IV	2012	TPT
The steam cycle used in electricity generation	1967	PE
The physics of power stations: Part I: Fossil fueled power stations	1975	PE
Prospects for solar electricity	1977	TPT
Removing the mystery of entropy and thermodynamics—Part II	2012	TPT
Graphic representation of quasi-static heat exchange	2018	TPT
The law of entropy increase—A Lab Experiment	2016	TPT
The second law of thermodynamics: Heat engines and refrigerators	1967	PE
A conspectus on US energy	2011	TPT
Desalting and nuclear energy	1971	TPT
Commentary on “Figuring Physics/Rapid Evaporation”	2007	TPT
Stirling engines for demonstration	1982	TPT

(Table continued)

Article title	Year	Journal
Topic 12—Astronomy: 2,7% “earth” + 1,9% “sun” + 1,7% “star” + 1,1% “astronomy” + 1,0% “planet” + 1,0% “space”		
Solar and lunar demonstrators	2009	PE
Simulating the phases of the Moon shortly after its formation	2014	TPT
An analemma experiment	2000	TPT
Exoplanets	2003	PE
Kepler’s third law and NASA’s Kepler Mission	2015	TPT
Whither does the Sun rove?	2011	TPT
A classroom activity and laboratory on astronomical scale	2017	TPT
Diurnal astronomy: Using sticks and threads to find our latitude on Earth	2012	TPT
Fixing the shadows while moving the Gnomon	2015	TPT
The view from Mimas	1988	TPT
Measuring global position using the Sun	2014	PE
A stellar demonstrator	2009	PE
Lookback time: Observing cosmic history	1989	TPT
Dark energy	2003	PE
Detecting our own solar system from afar	2004	TPT
Topic 13—Nuclear physics and medical physics: 1,0% “radiation” + 0,8% “sample” + 0,7% “electron” + 0,7% “energy” + 0,7% “cell” + 0,7% “detector”		
Semiconductor detectors	1970	TPT
Radiation physics and applications in therapeutic medicine	2001	PE
Fast neutron radiotherapy	1973	TPT
Research in biophysics: The high resolution scanning electron microscope	1975	TPT
Teaching about natural background radiation	2013	PE
An illustrated guide to measuring radiocarbon from archaeological samples	2004	PE
Chemical identification of surface monolayers	1976	TPT
Radiotherapy by external beams of ionizing radiation	1978	PE
Radon adsorbed in activated charcoal—a simple and safe radiation source for teaching practical radioactivity in schools and colleges	2012	PE
Radioactive consumer products in the classroom	1995	TPT
Nuclear medicine	2001	PE
Radiation exposure in our daily lives	1977	TPT
Physics in nuclear medicine	1978	PE
Diamond films and coatings: The flame deposition method and applications	1997	PE
Molecular beam epitaxy	1981	PE
Topic 14—Fundamental particles and interactions: 4,2% “particle” + 3,3% “energy” + 2,2% “electron” + 1,3% “mass” + 1,3% “quantum” + 1,1% “atom”		
Particles, Feynman diagrams, and all that	2006	PE
Medical imaging	1996	PE
The standard model	1992	PE
A temporary organization of the subatomic particles	1975	TPT
An article about a particle with charm?	1975	TPT
Meet the family: The leptons	1997	PE
Teaching elementary particle physics, part II	2011	TPT
Beta decay	1988	TPT
Looking for consistency in the construction and use of Feynman diagrams	2001	PE
Exploring the standard model of particles	2013	PE
Exploring quarks, gluons, and the Higgs boson	2013	PE
The origin of mass	1996	PE
Assessment for learning in physics investigations: Assessment criteria, questions, and feedback in marking	2006	PE
Let us have a coffee with the standard model of particle physics!	2017	PE
The fundamental interactions of matter (for teachers)	1977	PE

(Table continued)

Article title	Year	Journal
Topic 15—History and philosophy of physics: scientists, books, and ideas: 0,7% “book” + 0,5% “world” + 0,5% “scientist” + 0,5% “theory” + 0,5% “scientific” + 0,4% “idea”		
Resource letter SL-1 on science and literature	1966	TPT
Early science books and their women translators	1998	TPT
Lady Newton—an eighteenth century Marquise	1996	PE
Albert Einstein: His life	1979	PE
Where credit is due	1972	TPT
Assimilation and development in Arab scientific thought	1966	TPT
Isaac Newton—250th anniversary	1977	PE
Einstein, relativity, and the press	1980	TPT
Joseph Priestley, an early immigrant scientist	1976	TPT
Physics and faith	1987	PE
A non-believer looks at physics	1987	PE
Where credit is due the leaning tower of Pisa experiment	1972	TPT
Benjamin Thompson, Count Rumford	1976	TPT
A Copernicus quiz	1973	TPT
Galileo Galilei—Outline of his life and works	1966	TPT
Topic 16—Trends in Physics education: course structures and career pathways: 0,8% “pupil” + 0,7% “subject” + 0,6% “education” + 0,6% “project” + 0,4% “examination” + 0,4% “unit”		
TEC physics	1980	PE
Examination results	1969	PE
Occupation of successful candidates in the 1969 graduateship examination of the Institute of Physics	1972	PE
Physics courses at Loughborough	1978	PE
The Higher National Diploma in Applied Physics	1969	PE
Joint-honours degrees at Manchester	1978	PE
	1972	PE
The tyneside physics centre	1967	PE
Physics degree courses	1973	PE
Nonadvanced further education	1986	PE
The organization of applied physics degree courses in colleges of technology	1966	PE
Physics in the polytechnics	1980	PE
Technician engineers and technicians	1972	PE
The examining of advanced level practical physics by the joint matriculation board	1972	PE
The CEI view	1981	PE
Topic 17—Programs, texts, and teaching strategies: 1,1% “class” + 1,0% “program” + 1,0% “highschool” + 0,7% “college” + 0,7% “lab” + 0,7% “text”		
NOTES: A self-paced program of instruction at a 2-year Institution	1973	TPT
Old physics taught a new way	1971	TPT
The one-year, noncalculus physics course: An update	1988	TPT
Teaching physics: A human endeavor interview III	1977	TPT
The Waterworld	2004	TPT
Computer programs for physics lab	1982	TPT
Nearly 1.4 million high school physics students—Enrollments in AP and second-year courses up 26% even though number of graduates down in 2012–13	2014	TPT
“Retests”: A better method of test corrections	2011	TPT
Readability of college astronomy and physics texts III	1983	TPT
Teaching physics: A human endeavor Interview IV	1977	TPT
Update on the status of the one-year, noncalculus physics course	1994	TPT
Student selection of the textbook for an introductory physics course	2007	TPT
Editorial procedures	2002	TPT
How do you select your physics textbook?	1989	TPT
Teaching to teachers the course that they teach	1985	TPT

(Table continued)

Article title	Year	Journal
Topic 18—Demonstrations and apparatus in physics teaching: 3,0% “fig” + 1,2% “apparatus” + 0,8% “length” + 0,8% “demonstration” + 0,8% “cm” + 0,7% “spring”		
Simple self-lubricated electric motor for elementary physics lab	1983	TPT
Rotational motion demonstrator	1988	TPT
Three accessories for a rotating platform	1980	TPT
The sand pendulum	1987	TPT
Thermometer from a BIC ballpoint pen	1977	TPT
NOTES: A simple camera-panning device	1972	TPT
Apparatus for teaching physics. Classroom Foucault pendulum	1996	TPT
Apparatus for measuring Young’s modulus	2003	TPT
Rotating stool mounted on a low-friction hub	2000	TPT
The Iowa wave machines	2010	TPT
Versatile celestial globe for introductory astronomy	1980	TPT
Center of mass of a suspended slinky: An experiment	2004	TPT
A standing wave simulator	1989	TPT
Standing waves-a new twist	1983	TPT
Moment of inertia of a physical pendulum	1996	TPT
Topic 19—Data acquisition and measurement in Physics education: 2,5% “data” + 1,7% “measurement” + 1,1% “graph” + 1,0% “sensor” + 0,9% “model” + 0,7% “experimental”		
A novel real-time data acquisition using an Excel spreadsheet in pendulum experiment tool with light-based timer	2018	PE
Modeling human gait in high school	2018	PE
Detecting position using ARKit	2018	PE
Modeling physics with easy Java simulations	2007	TPT
An Arduino experiment to study free fall at schools	2018	PE
Using	2016	PE
A simple pendulum-based measurement of the role of data range in linear regression	2018	PE
Deviation from the mean in teaching uncertainties	2017	TPT
Advanced tools for smartphone-based experiments: Phyphox	2017	PE
The importance of measurement data spacing	2018	PE
A new position sensor to analyze rolling motion using an iPhone	2015	TPT
Teaching physics using Microsoft Excel	2019	PE
Driven damped harmonic oscillator resonance with an Arduino	2017	PE
Creating interactive physics simulations using the power of GeoGebra	2017	PE
Topic 20—Innovative learning strategies in physics education: 1,8% “learn” + 1,0% “activity” + 1,0% “question” + 1,0% “concept” + 0,9% “group” + 0,9% “research”		
Implications of research on learning for the education of prospective science and physics teachers	2001	PE
Reflection on solutions in the form of refutation texts versus problem-solving: The case of 8th graders studying simple electric circuits	2017	PE
Using the Force Concept Inventory to monitor student learning and to plan teaching	2002	PE
Learning from mistakes: The effect of students’ written self-diagnoses on subsequent problem-solving	2016	TPT
Dealing with the ambiguities of science inquiry	2016	TPT
Physics textbooks: Do they promote or inhibit students’ creative thinking	2015	PE
Self-diagnosis as a tool for supporting students’ conceptual understanding and achievements in physics: The case of 8th-graders studying force and ...	2017	PE
Teaching renewable energy using online PBL in investigating its effect on behavior towards energy conservation among Malaysian students: ANOVA re...	2017	PE
Impact of guided reflection with peers on the development of effective problem-solving strategies and physics learning	2016	TPT
Best practices for administering concept inventories	2017	TPT
Using categorization of problems as an instructional tool to help introductory students learn physics	2016	PE

(Table continued)

Article title	Year	Journal
Periscope: Looking into learning in best-practices physics classrooms	2018	TPT
Preparing teachers to teach physics and physical science by inquiry	2000	PE
Impact of interactive engagement on reducing the gender gap in quantum physics learning outcomes among senior secondary school students	2012	PE
Large-scale studies on the transferability of general problem-solving skills and the pedagogic potential of physics	2013	PE

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