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Mapping Learning Management System–Based Flipped Classroom Research Trends in Physics Education (2020-2025): A Bibliometric Analysis

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ABSTRACT

Objective: *A bibliometric analysis was conducted to comprehensively map publication trends, conceptual structures, shifts in research focus, and knowledge gaps regarding Learning Management System (LMS)-based flipped classrooms in physics education between 2020 and 2025.* ***Method:*** *A quantitative descriptive approach was employed via bibliometric analysis guided by the PRISMA 2020 screening protocol. We processed 239 documents retrieved from the Scopus database using Scopus Web Analytics for statistical performance analysis and science mapping techniques.* ***Results:*** *Findings indicate that annual publication dynamics fluctuated but rebounded in 2025, accumulating 2,872 citations and an h-index of 24. The research's conceptual network is divided into seven main clusters representing the relationships between flipped classroom pedagogy, e-learning, and learning analytics. A thematic evolution map reveals a paradigm shift from emergency adaptation responses to remote learning (2020–2021) toward the utilization of data analytics, the development of critical thinking skills, and self-regulated learning (2024–2025).* ***Novelty:*** *This research maps the LMS as a conceptual dimension integrated with the pedagogical characteristics of physics education, particularly in supporting the learning of abstract physics concepts. These findings expand understanding of flipped classroom evolution by showing the trajectory of LMS development from mere digital learning infrastructure to environments that support pre-class diagnostic quizzes, interactive simulations (such as PhET), learning analytics, and the cultivation of critical thinking and self-regulated learning skills. Consequently, this study provides a conceptual foundation for developing LMS-based flipped classroom designs that are more adaptive and aligned with the specific characteristics of physics learning.*

INTRODUCTION

Digital transformation in physics education has shifted from the mere digitization of materials and the provision of electronic formula repositories toward the integration of technology, organizational governance, and structured social interaction (Castro Benavides et al., 2020). Currently, physics education faces fundamental challenges, specifically high cognitive load and prevalent student misconceptions stemming from the subject's abstract and counterintuitive nature, which demands understanding multiple representations ranging from conceptual and mathematical to visual aspects. This digital paradigm shift necessitates a reorientation of the physics educator's role from a conventional transmitter of knowledge to a facilitator, mentor, and evaluator of the scientific exploration process (Haleem et al., 2022). A key supporting infrastructure in this transformation is the Learning Management System (LMS). However, successful LMS use depends heavily on information quality, service support, and the readiness of both educators and students (Al-Fraihat et al., 2020). To date, the use of platforms like Moodle in STEM (Science, Technology, Engineering, and Mathematics) education has often been limited to managing assignments and online assessments, lacking the support of a structured pedagogical design (Gamage et al., 2022). Therefore, an LMS should be positioned as supporting infrastructure that reinforces the pedagogical framework, rather than merely serving as a repository for passive instructional materials.

One pedagogical design that integrates effectively with an LMS is the "flipped classroom." Unlike conventional LMS usage, which tends to function passively as a document repository, an LMS-based flipped learning environment offers substantive advantages, such as learning analytics features to monitor student readiness, automated pre-class diagnostic testing, and the integration of interactive simulations that allow students to explore independently before proceeding to face-to-face sessions (Baig & Yadegaridehkordi, 2023). This approach shifts procedural material to pre-class sessions and optimizes class time for discussion, complex problem-solving, and proof-of-concept activities (Strelan et al., 2020). In STEM education, the implementation of such an integrated LMS environment is supported by empirical evidence from meta-analyses: LMS-based flipped classroom models have been shown to significantly improve students' cognitive learning outcomes with effect sizes ranging from $g = 0.35$ to $g = 0.47$ and reduce failure rates by 33% compared to conventional lecture methods (Freeman et al., 2014; van Alten et al., 2020). Success depends heavily on the synchronization between pre-class and in-class activities, student readiness, and the quality of instructional design (Gong et al., 2024). These aspects are crucial in determining how well the flipped classroom model can foster student engagement and achieve learning objectives.

In line with this, the cognitive benefits of the flipped classroom model can be maximized when combined with collaborative learning and active problem-solving strategies (Shi et al., 2020). Cross-disciplinary evidence indicates that pre-learning materials become far more meaningful when designed to support experimental activities and contextual discussions within the classroom (Fung, 2020; Hew et al., 2021; Kapur et al., 2022), particularly when reinforced by structured motivational strategies (Karabatak & Polat, 2020). Integrating LMS platforms with the flipped classroom model is particularly urgent in physics education, as the discipline requires conceptual discussion, problem-solving, demonstrations, and simulation-based experiments. In practice, however, limited class time is often consumed by lectures on formulas, leaving little opportunity to address misconceptions regarding complex topics such as mechanics, thermodynamics, or electromagnetism. A review of 30 studies indicates that while pre-class physics activities typically incorporate videos, reading materials, and quizzes, reporting on them lacks the detail needed to draw comprehensive conclusions about their applicability across diverse contexts (Tunggyshbay et al., 2023). Hung and Young (2021) further emphasize that students' prior knowledge significantly influences the effectiveness of flipped learning in thermal physics. Meanwhile, Lintangesukmanjaya et al. (2024) identify an urgent need for interactive digital media and virtual simulations in physics education to visualize abstract phenomena. These findings reinforce the premise that lesson preparation, interactivity, visualization, and continuous feedback are fundamental pillars of LMS-based physics instruction.

Previous bibliometric studies have mapped publication trends, dominant themes, national contributions, and research networks concerning the flipped classroom in general, yet they did not restrict their analysis to the specific domains of physics education and LMS utilization (Del Arco et al., 2022; Julia et al., 2020). Dwikoranto et al. (2023) mapped research on Massive Open Online Courses (MOOCs) within Learning Management Systems (LMS) in higher education but did not focus on the flipped classroom model or physics education. Furthermore, Agusta et al. (2025) examined flipped classroom trends in physics education but compiled their research corpus based solely on the keywords "flipped classroom" and "physics," without establishing the LMS as a primary conceptual boundary. This approach indicates that while studies on the flipped classroom in physics education have been conducted, the role of the LMS as a crucial component of digital learning integration has not been a central focus of such mapping.

Consequently, the research gap is the absence of a comprehensive mapping that integrates the LMS, the flipped classroom model, and physics education into a unified analytical framework. The novelty of this study lies in positioning the LMS as a substantive conceptual dimension in constructing the research corpus, rather than merely as a general supporting technology. This positioning enables the identification and mapping of research that explicitly links LMS functions with flipped classroom pedagogical designs and the characteristics of physics learning, particularly regarding the learning of abstract physics concepts. Unlike previous studies that examined flipped classroom trends in physics education without treating the LMS as a primary conceptual dimension, this study provides a more focused mapping of the interrelationships among LMS, flipped classroom pedagogy, and physics education. To address this gap, this study aims to map research trends on LMS-based flipped classrooms in physics education during 2020–2025. The mapping includes an analysis of annual publication trends, document-type proportions, the distribution of contributions from countries with the highest research productivity, keyword networks and their evolution, and a qualitative analysis of key findings from the five most-cited documents to reveal the conceptual structure, shifts in research focus, and under-explored areas. Through this focus, the study provides a more specific conceptual representation of the development of research on LMS-based flipped classroom in physics education during the 2020–2025 period.

RESEARCH METHOD

Research Design

This study uses a quantitative descriptive design and a bibliometric approach to map publication trends, conceptual structures, and intellectual networks on Learning Management System (LMS)-based flipped classrooms in physics education. To ensure a transparent, systematic, and replicable document selection process, the study utilizes the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines as a framework for identifying, screening, and selecting the documents to be analyzed (Page et al., 2021). In this study, PRISMA 2020 is applied only to document identification and screening, while the primary analysis uses a bibliometric approach. The bibliometric analysis framework is adapted from the stages proposed by Donthu et al. (2021), comprising keyword determination, preliminary searching, data collection, data screening and refinement, data analysis, and result interpretation. The detailed research workflow is presented in Figure 1 below.

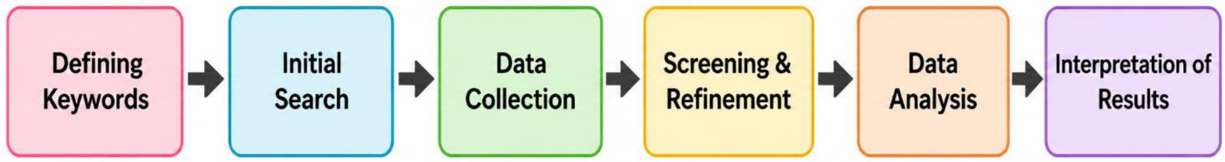

Figure 1. Bibliometric analysis workflow (Dawana et al., 2022)

As illustrated in Figure 1, the research workflow follows six systematic, interconnected stages. The keyword definition stage involves identifying phrase combinations that encompass three primary conceptual domains. The initial search stage runs a search syntax in the Scopus database without applying initial restrictive criteria to map the scope of relevant literature. Subsequently, during the data collection stage, comprehensive metadata is downloaded from the Scopus database (on July 13, 2026) in CSV and RIS formats. The screening and refinement stage applies inclusion and exclusion criteria based on the PRISMA workflow to establish the final corpus. The filtered data is then processed during the data analysis stage using descriptive statistics and visual mapping of knowledge networks. Finally, the interpretation of results stage involves describing quantitative trends and patterns of scholarly evolution to identify research gaps, aligning with the objectives established in the introduction.

Keyword Development and Search Strategy

The document search strategy is formulated by combining terms representing the three research domains using the following search syntax: TITLE-ABS-KEY ("Learning Management System" OR "LMS") AND TITLE-ABS-KEY ("Flipped Classroom" OR "Flipped Learning") AND TITLE-ABS-KEY ("Physics Education" OR "Physics" OR "STEM" OR "Science"). The selection of these keyword combinations is grounded in a robust rationale consistent with the research framework. The "Learning Management System" (or LMS) domain is included to delimit the digital technology infrastructure that manages pre-class learning flows and student interactions. The "Flipped Classroom" (or "Flipped Learning") domain is employed to specify the pedagogical framework that shifts procedural instructional activities outside the classroom. Meanwhile, the "Physics Education" and "Physics" domains are included to capture articles focusing directly on the field of physics. The inclusion of the terms "STEM" and "Science" is based on the rationale that research on LMS-based and flipped-classroom physics learning is frequently published within the context of integrated science education or STEM disciplines (Donthu et al., 2021). An initial Scopus search yielded 49,797 documents overall; however, after applying the keyword combination syntax to titles, abstracts, and keywords, 393 relevant documents were identified, excluding the 49,404 documents that did not meet these combined criteria.

Document Screening and Selection

Document the subsequent corpus screening and selection procedures were carried out systematically following the PRISMA workflow presented in Figure 2 below.

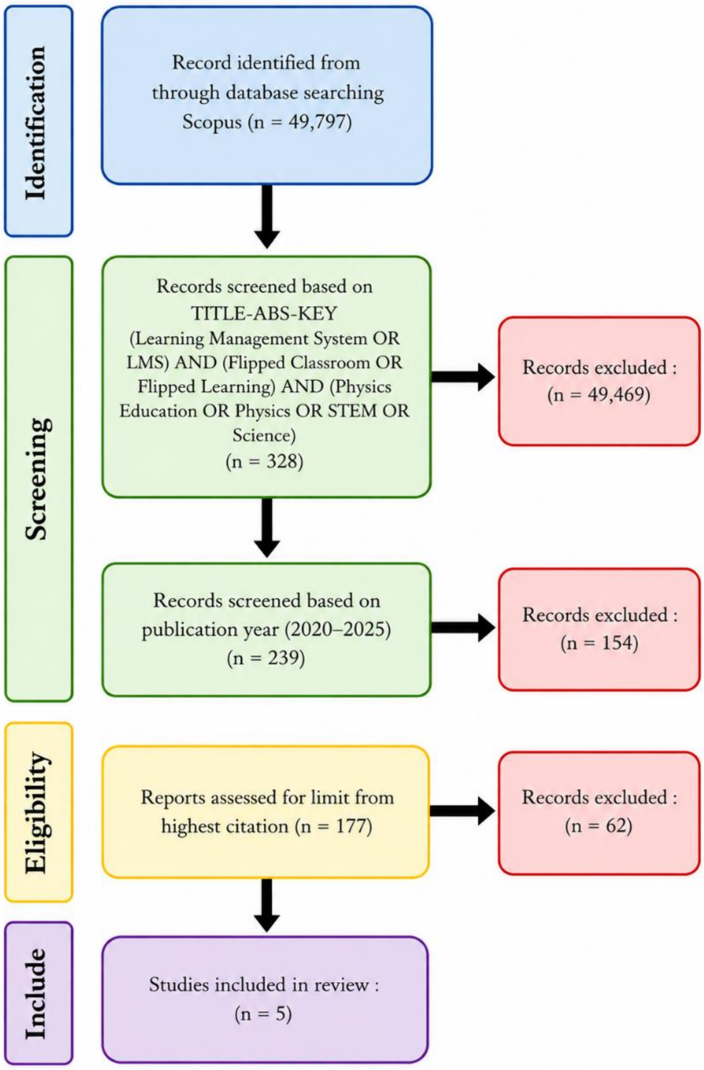

Figure 2. PRISMA flowchart of the document selection process

A total of 393 documents identified in the initial search phase were filtered by publication date (2020-2025). This year-range filtering resulted in 239 documents meeting the inclusion criteria, while 154 documents were excluded because they were published outside that period. This study did not apply a document type filter, so all 239 documents, consisting of journal articles, proceedings, and book chapters, were designated as the primary corpus. As of July 13, 2026, 177 of these documents had received at least one citation, while 62 had not been cited (dominated by publications from 2024–2025).

The rationale for presenting and qualitatively analyzing the top five most-cited papers is to provide an in-depth overview of the pedagogical focus and key scientific domains most influential in this literature. Quantitative mapping using VOSviewer and Scopus can show broad numerical trends and keyword networks, but it does not describe the details of the main findings of these top studies. Therefore, these five articles were analyzed qualitatively (content analysis) to extract key findings regarding the integration of AI-enabled personalized recommendations, the adoption of gamification elements in flipped learning, the impact of the polarizing effect on learning outcomes, and the factors of infrastructure readiness and digital competency in virtual learning environments (LMS) during/after the COVID-19 pandemic. Selecting these five documents did not reduce the main corpus; all 239 documents were analyzed in full to map publication trends, country contributions, and keyword networks, so the study's main conclusions were supported by a comprehensive analysis of the 239 documents as a whole.

Data Collection and Bibliometric Analysis

The research data comprises 239 documents that met the search strategy criteria and were published between 2020 and 2025. The information collected includes the year of publication, document type, authors' countries of origin, keywords, and citation counts. The data analysis technique combines performance analysis and science mapping, aligned directly with the analytical focus outlined in the introduction (Moral-Muñoz et al., 2020). Performance analysis was conducted by processing the metadata of the 239 documents using Scopus Web Analytics' built-in features to extract data on annual publication growth trends (2020–2025), document type proportions, and the distribution of contributions by country. Science mapping was carried out by importing the complete metadata into VOSviewer software (version 1.6.20), employing keyword co-occurrence analysis to map keyword networks and overlay visualization to analyze keyword evolution.

Scope of Interpretation

The bibliometric results are interpreted both descriptively and analytically by synthesizing quantitative findings from Scopus and VOSviewer with a qualitative analysis of the key findings from the five most highly cited articles. This interpretation explains publication patterns, shifts in research emphasis, thematic connections, and the evolution of the knowledge structure regarding LMS-based flipped classrooms between 2020 and 2025, with the aim of identifying research gaps and practical implications. The interpretation is strictly limited to bibliometric evidence and supporting literature; consequently, the mapping results are intended solely to illustrate the development of the knowledge structure and are not used to directly assess learning effectiveness or establish causal relationships between variables (Mukherjee et al., 2022).

RESULTS AND DISCUSSION

Results

This analysis of 239 Scopus documents maps the development and conceptual structure of research on Learning Management System (LMS)-based flipped classrooms in physics education from 2020 to 2025. The bibliometric evaluation covers publication volume trends, annual citation accumulation, document types, geographical contributions by country, keyword network structures, and thematic evolution maps. Figure 3 below presents the dynamics of annual publication volume during 2020–2025.

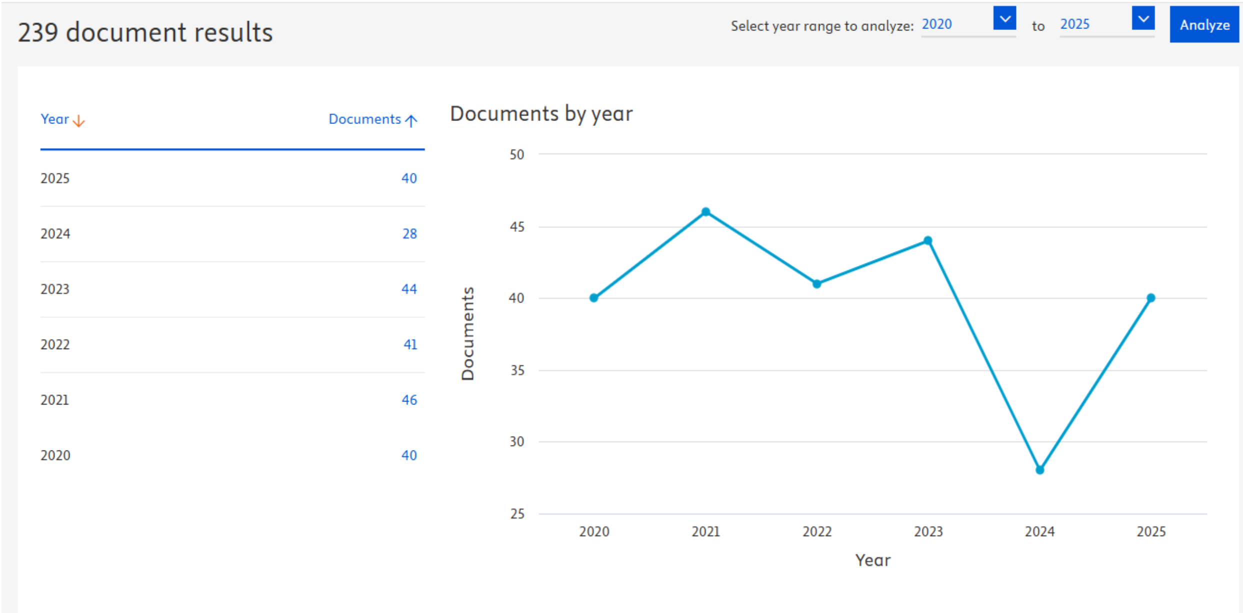

Figure 3. Publication trends from 2020 to 2025

The number of publications shows a non-linear, fluctuating pattern. Research activity began with 40 documents in 2020, rose to a peak of 46 documents in 2021, then declined slightly to 41 documents in 2022, and rose to 44 documents in 2023. The publication count dropped to 28 documents in 2024 before rising again to 40 documents in 2025. The high volume of articles during the 2020–2021 period is closely linked to the emergency adoption of remote teaching during the COVID-19 pandemic, when Learning Management Systems (LMS) and the flipped classroom approach emerged as primary solutions to instructional disruptions (Bond et al., 2021; Haleem et al., 2022). The resurgence in publication volume in 2025 indicates that this model has become an integrated, permanent pedagogical practice in physics education. Figure 4 below presents the dynamics of publication volume and the patterns of sustained citation accumulation from 2020 to 2025.

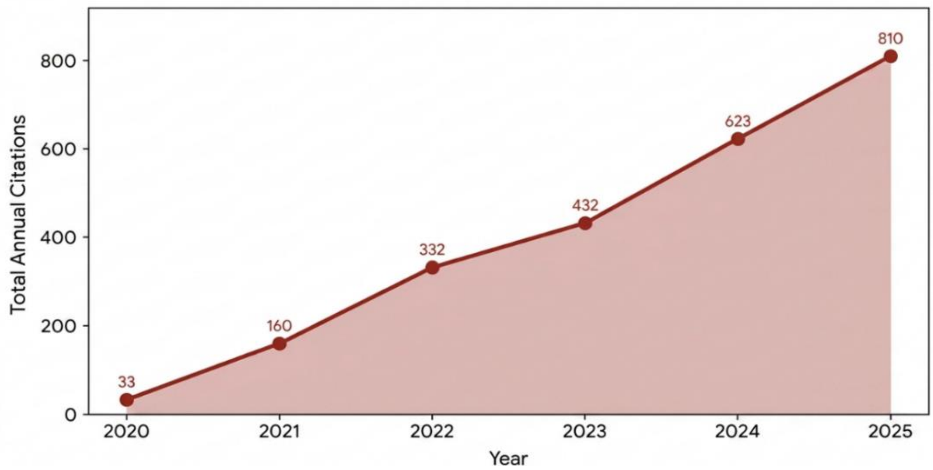

Figure 4. Trends in publications and annual citation accumulation in 2020–2025

Bibliometric analysis of the 239-document corpus reveals significant scientific impact, with a cumulative total of 2,872 citations and an h-index of 24. Within this research corpus, 177 documents (74.1%) have garnered at least one citation, while the remaining 62 documents (25.9%) have yet to record any citations. This high proportion of cited documents underscores the strong academic relevance and global appeal of integrating Learning Management Systems (LMS) and flipped learning. Specifically, the annual citation accumulation curve demonstrates a consistently rising exponential trend: starting with 33 citations in 2020, followed by 160 in 2021, 332 in 2022, 432 in 2023, and 623 in 2024, before peaking at 810 citations in 2025. The high volume of accumulated citations for publications from the early period (2020–2022) was driven by the rapid, emergency adoption of remote learning during the COVID-19 pandemic, which necessitated a global reorientation toward digital-based learning methodologies (Bond et al., 2021; Haleem et al., 2022).

Meanwhile, the 62 uncited documents are largely concentrated among articles published recently, during the 2024–2025 period. This situation does not indicate a decline in research quality; rather, it is a natural consequence of "citation lag," the time required for a new publication to be read, reviewed, and subsequently cited in future scholarly works. Figure 5 below presents the distribution of the forms and types of scholarly documents comprising this literature corpus.

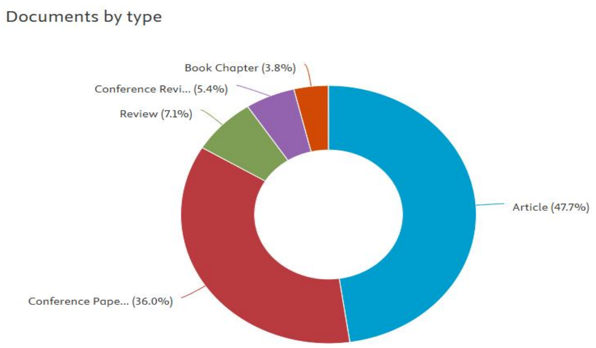

Figure 5. Documents by type

Publications are dominated by indexed journal articles (47.7%) and conference papers (36.0%), followed by review articles (7.1%), conference reviews (5.4%), and book chapters (3.8%). The predominance of journal articles underscores that the research findings have undergone a rigorous peer-review process, thereby ensuring high methodological reliability. The significant proportion of conference papers reflects the rapid dissemination of learning technology innovations within scholarly forums. Conversely, the relatively small share of review articles indicates that this research domain remains dominated by empirical development and field trials rather than conceptual literature synthesis. Figure 6 below shows the geographical distribution of publications by the authors' countries of origin.

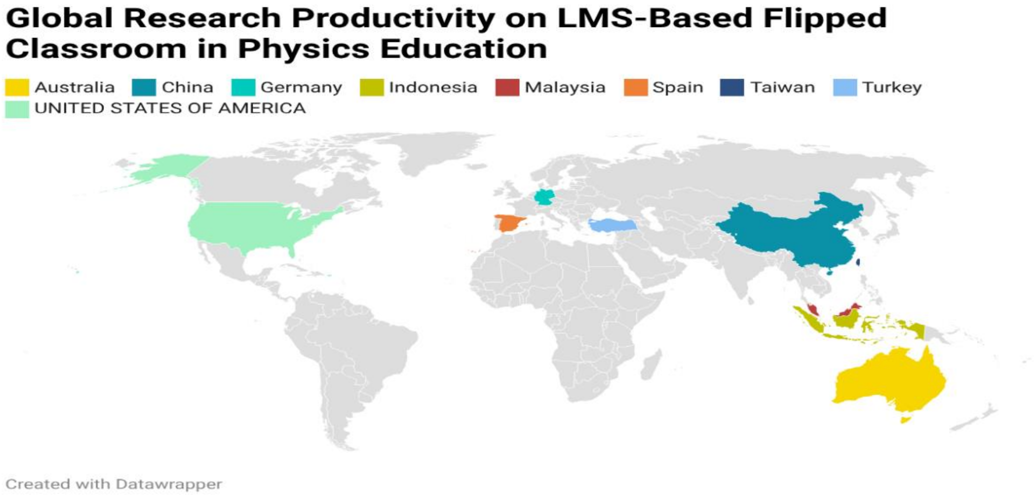

Figure 6. Distribution of publications by country

Publication contributions are distributed across various regions, including the United States (26 documents), China (12 documents), Indonesia (9 documents), Spain (7 documents), and Turkey (7 documents), as well as Malaysia, Germany, Australia, and Taiwan. Each region's primary research focus directly influences these national contribution trends. In developing nations such as Indonesia, Malaysia, and Turkey, research trends are driven by the urgent need to adopt open-source LMS platforms like Moodle, digitize curricula, and enhance the pedagogical capacity of prospective physics teachers to expand STEM learning accessibility. Conversely, in developed nations such as the United States, China, Germany, Australia, and Taiwan, research trends lean toward advanced technological innovations backed by substantial grant funding, including the integration of learning analytics, AI-driven adaptive learning systems, and virtual laboratory experiments in physics classrooms.

Conceptual Structure of the Keyword Network

The mapping of relationships between keywords and thematic interconnections within the research corpus is shown in Figure 7 below.

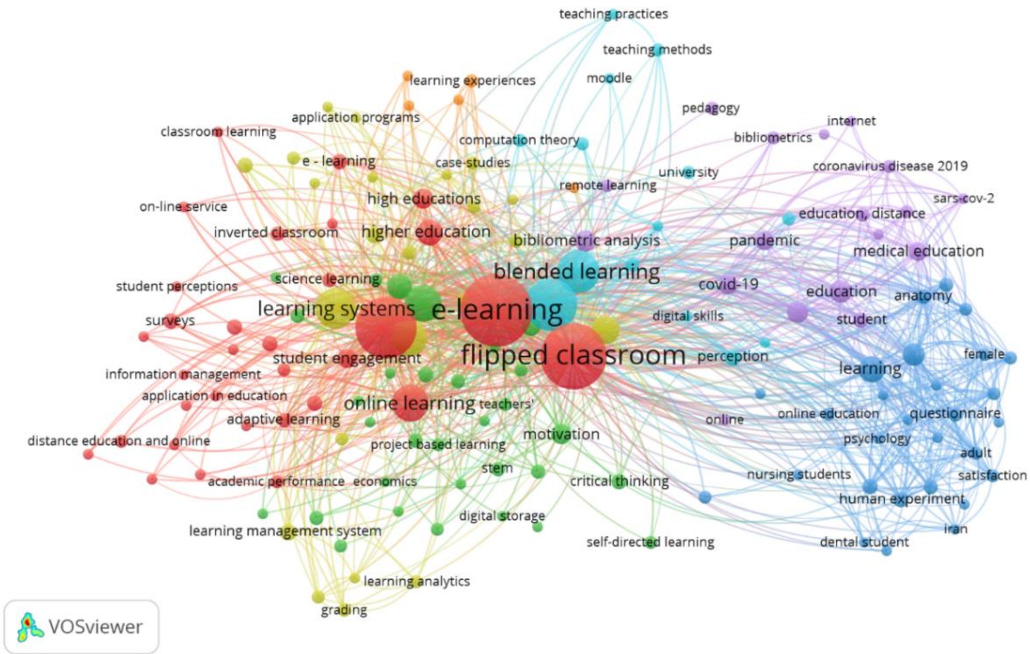

Figure 7. Shared network keywords

Based on a bibliometric analysis using VOSviewer on 151 keywords meeting the threshold criteria, a conceptual network was formed comprising 2,172 links with a cumulative Total Link Strength (TLS) of 4,223. The most dominant keywords based on occurrence frequency weight and connectivity are flipped classroom, e-learning, students, blended learning, online learning, learning, and higher education. The high occurrence and connectivity weights of these primary keywords directly influenced cluster formation within the network. Keywords with high TLS act as central nodes (hubs) with high centrality, attracting surrounding secondary keywords based on association strength, thereby dividing the entire conceptual network into seven interconnected thematic clusters.

The first cluster (red) focuses on flipped classroom pedagogy and student engagement, grouping keywords such as flipped classroom, students, student engagement, student perceptions, inverted classroom, surveys, and academic performance. Literature reviews confirm that this cluster reflects a primary research focus on the effectiveness of the flipped classroom in enhancing students' active participation and academic achievement (Bredow et al., 2021; Strelan et al., 2020). The second cluster (green) represents the domains of online learning, LMS, and physics/STEM education, encompassing e-learning, online learning, knowledge management, motivation, critical thinking, learning management system, pedagogical approach, STEM, and physics. This cluster forms the core of research demonstrating that LMS integration in physics education is oriented toward developing critical thinking skills and learning motivation through structured pedagogical approaches (Bitzenbauer & Hennig, 2023; Tunggyshbay et al., 2023).

The third cluster (blue) emphasizes psychological aspects, human-centered experiments, and applied evaluations, covering keywords such as learning, psychology, human experiment, procedures, questionnaire, satisfaction, and dental student.

Consistent with the literature, this cluster indicates that the measurement of psychological impact and learning satisfaction has been extensively examined empirically within health disciplines and instructional experiments (Hew & Lo, 2018; Tang et al., 2020). The fourth cluster (yellow) focuses on higher education and learning analytics, encompassing keywords such as higher education, personnel training, grading, learning analytics, and classroom learning. The literature review explains that this cluster highlights institutions' role in leveraging data analytics to monitor teaching and learning processes (Liu et al., 2024; Yoon et al., 2021).

The fifth cluster (purple) depicts the context of distance learning and the response to the pandemic crisis, featuring keywords such as COVID-19, pandemic, coronavirus disease 2019, distance learning, SARS-CoV-2, and medical education. This cluster underscores that the COVID-19 pandemic served as a primary catalyst for the massive global adoption of digital-based flipped classroom methods (Adnan & Anwar, 2020; Bond et al., 2021). The sixth cluster (cyan/light blue) centers on blended learning strategies and digital skills, incorporating keywords such as blended learning, digital skills, active learning, and perception. The literature supports the view that combining active learning with digital approaches enhances the effectiveness of blended learning (Al-Samarraie et al., 2020; Gamage et al., 2022). The seventh cluster (orange) highlights teaching practices, learning experiences, and the Moodle platform, utilizing keywords such as Moodle, teaching practices, teaching methods, pedagogy, learning experiences, computation theory, and case studies. This cluster emphasizes the technical role of open-source LMS platforms like Moodle in facilitating structured teaching practices and learning experiences (Baig & Yadegaridehkordi, 2023; Han, 2022).

Evolution of Research Topics Based on Time Dimension

The dynamics of the shift in research topic focus from 2020 to 2025 are mapped in Figure 8 below.

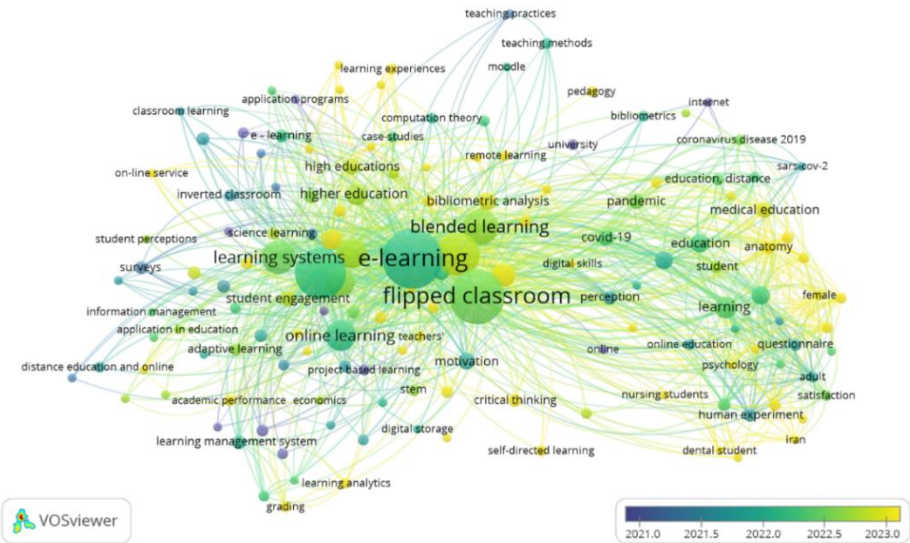

Figure 8. Overlay visualization of keyword evolution

Figure 8 illustrates a thematic shift from infrastructure and online instruction to the student learning process. Terms such as learning management systems, distance education, online services, universities, surveys, and flipped classrooms emerged during the initial 2020–2021 period in response to the need for emergency technical adaptation. These themes then shifted toward e-learning, flipped classrooms, blended learning, and the Moodle platform during 2022–2023, eventually culminating in a focus on learning experiences, critical thinking, self-regulated learning, learning analytics, and case studies in 2024–2025. The colors in the visualization indicate the average year of appearance rather than the initial date of keyword usage. This progression reflects an increasing emphasis on data utilization, personalization, reflection, and self-regulation. Research on reflective dashboards, learning analytics-based interventions, and self-regulation support within flipped classrooms supports these trends (Liu et al., 2024; Ustun et al., 2023; Yoon et al., 2021). However, success remains contingent upon system quality, instructor support, and student readiness (Al-Fraihat et al., 2020; Han, 2022).

Based on this thematic evolution, a research agenda is proposed for the 2026–2030 period, categorized by priority level or intensity. At the high-intensity, top-priority level, research is strongly recommended to focus on integrating AI-driven Adaptive Learning Analytics into LMS platforms for flipped classrooms, specifically targeting real-time tracking of physics misconceptions and the provision of automated feedback during pre-class activities. At the medium-intensity level, projected critical topics include developing self-regulated learning dashboards and using PhET interactive simulations and virtual laboratories embedded directly into the LMS workflow to bridge understanding of abstract physics theories. Meanwhile, at a specific level of intensity or regarding a new research niche, it is recommended that research explore Multimodal Learning Analytics (MMLA) to monitor students' metacognition, cognitive load, and collaboration dynamics. At the same time, students engage in interactive physics problem-solving in the classroom.

Five Most Cited Documents

A total of 177 out of 239 documents have received at least one citation. These documents are ranked based on the number of Scopus citations recorded as of July 13, 2026. Table 1 presents the five documents with the most citations. The number of citations indicates relative academic impact, not the sole measure of research quality.

Table 1. Five most cited Articles

No.	Author & Year	SJR (Quartile)	Citations	Main Findings
1.	Huang et al. (2023)	3,82 (Q1)	522	The integration of an artificial intelligence (AI)-based recommendation system into the flipped classroom can enhance student engagement, motivation, and learning

No.	Author & Year	SJR (Quartile)	Citations	Main Findings
				outcomes. The personalization of learning materials makes the learning process more adaptive, thereby providing greater benefits to students with moderate levels of motivation.
2.	Camargo et al. (2020)	0,61 (Q2)	175	Online learning has proven effective in ensuring the continuity of the educational process during the COVID-19 pandemic. The effectiveness of its implementation is influenced by technological readiness, educators' competencies, the quality of learning interactions, and students' ability to adapt to the digital learning environment.
3.	Stöhr et al. (2020)	3,82 (Q1)	164	The implementation of the online flipped classroom has not yet led to a significant improvement in students' average learning outcomes. On the contrary, the disparity in learning outcomes among students has widened, making it necessary to adopt teaching strategies that can accommodate the diversity of students' characteristics.
4.	Torres Martín et al. (2021)	0,66 (Q1)	163	The COVID-19 pandemic has accelerated the adoption of virtual learning environments across various educational institutions. The success of this implementation depends on the readiness of the infrastructure, educators' digital competencies, and students' ability to engage in technology-based learning.
5.	Ekici (2021)	1,35 (Q1)	144	The use of gamification in flipped learning has a positive

No.	Author & Year	SJR (Quartile)	Citations	Main Findings
				impact on students' motivation, participation, engagement, and learning outcomes. The use of elements such as points, badges, and leaderboards can create a more engaging learning experience and encourage student engagement throughout the learning process.

The five articles cover the transition to virtual learning, the varying impacts of the online flipped classroom, and the development of adaptive learning. Camargo et al. (2020) show that the transition to online learning is feasible, but the learning structure still needs strengthening. Torres Martín et al. (2021) found that virtual platforms and active methodologies do not always yield a satisfactory learning experience when support, instructor engagement, and digital competencies are insufficient. In an applied physics course, Stöhr et al. (2020) found no significant difference in average performance between campus-based learning and the online flipped classroom. However, they observed greater performance variation in the online format.

Variations in readiness, motivation, and engagement subsequently became a focus in developing personalization and gamification. Huang et al. (2023) demonstrated that AI-based video recommendations and LMS data enhance engagement and performance, particularly among learners with moderate motivation. Ekici (2021) demonstrated that gamification supports motivation, participation, and performance in flipped learning. These findings indicate that the benefits of the flipped classroom depend not only on technology but also on system support, activity design, learner characteristics, assessment, and the instructor's role. Based on their scope, none of the articles in Table 1 focuses primarily on LMS, the flipped classroom, and physics education as a single main focus. Huang et al. (2023) link LMS to the flipped classroom in programming education, while Stöhr et al. (2020) use the context of applied physics without focusing on integrating LMS functions. Other articles discuss online learning, virtual environments, or gamification in a broader context. Thus, overlap among these three domains remains limited, even among the most highly cited articles.

Discussion

Fluctuations in publication numbers from 2020 to 2025 indicate that the research landscape regarding Learning Management System (LMS)-based flipped classrooms remains in a consolidation phase and has not yet established a linear growth pattern. The rapid shift to online learning during the COVID-19 pandemic was a primary accelerator of the global popularity of the flipped classroom (Divjak et al., 2022). However, this surge was not driven by a single factor. The rise of the flipped classroom as a hot topic in 21stcentury literature is rooted in an instructional paradigm shift from teacher-centered to student-centered learning. In science education, particularly in physics, dense and abstract course material often creates time constraints when concept transmission relies solely on conventional face-to-face interaction. The flipped classroom offers a strategic solution by shifting the initial cognitive load outside the classroom via digital media, thereby maximizing face-to-face time for active learning, problem-solving, and experimentation (Klein et al., 2021). The prevalence of journal articles and conference papers demonstrates the field's dynamic nature, characterized by rigorous academic validation and the rapid dissemination of technological innovations. The broad geographic distribution, with strong activity hubs in Asia and Europe, confirms higher education institutions' strong commitment to adopting digital transformation (Birgili et al., 2021). However, keyword network analysis reveals that the term "LMS" and technical terms specific to physics education have not yet merged into a dominant, unified theme. Previous research has tended to examine the flipped classroom within the general frameworks of pedagogy and user perception (Kushairi & Ahmi, 2021). This highlights a theoretical gap: the convergence of LMS capabilities, flipped classroom methodology, and the specific characteristics of physics education has not yet been formulated into a solid framework. The Evolution of 21st-Century LMS Capabilities: Advantages, Disadvantages, and Limitations in Physics Education

Keyword evolution mapping reveals a functional shift in 21st-century LMSs from mere static repositories (file dumps) to data-driven learning environments equipped with learning analytics, multimedia interactivity, and automated feedback mechanisms (van Alten et al., 2020). Modern LMSs can track student learning behaviors (learning telemetry), monitor access duration, measure initial understanding levels via diagnostic quizzes, and facilitate independent, self-regulated learning (Cevikbas & Kaiser, 2022). The use of LMSs in physics education offers several advantages, including facilitating multiple representations of abstract physics concepts through interactive PhET simulations, providing pre-class formative assessment tools to identify misconceptions in real-time, and presenting analytical data that enables educators to implement targeted pedagogical interventions. However, LMSs also have drawbacks, such as the need for significant investment in infrastructure and content development time, the potential for extraneous cognitive load caused by complex system navigation, and the risk of reduced social engagement if asynchronous interactions are not dynamically designed. Regarding whether an LMS can be used for every physics topic, the answer is that it cannot be applied uniformly without methodological adaptation. LMSs are highly effective for physics material focused on conceptual understanding, theoretical analysis, and mathematical problem-solving, such as quantum mechanics, thermodynamics, or electromagnetism, with the aid of simulations and digital visualizations. Conversely, LMS face fundamental limitations regarding physics topics that require psychomotor skills, direct equipment manipulation, and kinesthetic experiences in a physical laboratory setting, such as assembling complex electrical circuits, calibrating optical instruments, or performing applied mechanics measurements. Tactile skills, experimental intuition, and handling measurement uncertainty (error analysis) cannot be fully replaced by virtual laboratories or LMS modules; therefore, for experimental physics topics, the LMS should serve as a support tool for pre-lab preparation rather than a complete substitute for hands-on laboratory work.

The effectiveness of integrating an LMS with the flipped classroom model in physics education rests on a synthesis of key learning theories and frameworks from Physics Education Research (PER). Drawing on Vygotsky's Social Constructivism and Piaget's Cognitive Constructivism, the LMS facilitates independent knowledge construction during the pre-class phase, where students build initial schemas. At the same time, face-to-face classroom interactions serve as a Zone of Proximal Development (ZPD) for solving complex physics problems through collaborative discussion. Aligned with Sweller's Cognitive Load Theory, the LMS-based flipped classroom distributes the high cognitive load inherent in physics by shifting foundational "germane load" activities to an asynchronous LMS environment; this frees up students' working memory capacity during face-to-face sessions to tackle tasks requiring higher-order thinking skills (HOTS).

Recent developments in Physics Education Research show that the Just-in-Time Teaching (JiTT) method, combined with LMS-based conceptual quizzes, enables educators to analyze student misconceptions hours before the lecture, allowing for targeted adjustments to classroom teaching strategies (Bitzenbauer & Hennig, 2023; Tunggyshbay et al., 2023). Furthermore, the LMS supports modeling instruction approaches and inquiry-based learning environments by presenting physical phenomena at the outset and guiding the formation of mental models before quantitative verification in the classroom (Hung & Young, 2021; Lintangesukmanjaya et al., 2024). Ultimately, the success of this theoretical synthesis requires physics educators to possess robust Technological Pedagogical Content Knowledge (TPACK) to align specific LMS features, the flipped classroom method, and the structure of physics content effectively (Agusta et al., 2025; Castro Benavides et al., 2020). Synthesis of Empirical Findings and Lessons from High-Impact Articles

Meta-analyses and empirical evidence confirm that the cognitive benefits of the flipped classroom model depend heavily on the quality of instructional design and the presence of structured motivational strategies within the Learning Management System (LMS) to sustain active student engagement (Shi et al., 2020; Fung, 2020; Karabatak & Polat, 2020). A review of the five most highly cited articles deepens this understanding; Camargo et al. (2020) and Torres Martín et al. (2021) highlight that the transition to a virtual environment is prone to failure unless supported by educator digital competence and adequate infrastructure. In applied physics, Stöhr et al. (2020) found that shifting to an online flipped classroom did not automatically boost average class grades; instead, it widened the performance gap between high- and low-achieving students. This phenomenon supports Idsardi et al. (2023) that merely converting lectures into videos does not guarantee improved performance. To address this disparity, integrating AI-based personalized analytics (Huang et al., 2023) and implementing gamification elements (Ekici, 2021) serve as vital tools in 21st-century LMS platforms for maintaining the motivation of average- and low-achieving students. Regarding physics laboratory work, using an LMS for pre-class preparation has been shown to optimize laboratory time, allowing face-to-face sessions to focus on data analysis, conceptual clarification, and reflective discussion (Gómez-Tejedor et al., 2020). The LMS achieves its greatest pedagogical significance when asynchronous activities within the system are directly and meaningfully linked to synchronous classroom interactions (Hew et al., 2020; Torres-Martín et al., 2022).

Based on bibliometric findings, cluster analysis, and theoretical synthesis, this study formulated comprehensive operational recommendations and future research directions. For physics educators and instructional designers, they should optimize the application of differentiated learning principles by leveraging LMS analytics features to map student readiness and provide tailored scaffolding interventions (adaptive feedback). In experimental laboratory work, instructors should adopt a hybrid lab framework, using the LMS for interactive simulations (such as PhET), safety procedure comprehension, and foundational theory analysis during the pre-class phase, while reserving the physical laboratory space for data collection and handling experimental errors. Furthermore, instructors are advised to integrate the Just-in-Time Teaching (JiTT) cycle by administering short conceptual quizzes on the LMS before class to provide rapid feedback (diagnostic loop). For technology developers, 21st-century LMS platforms should feature PER-based Learning Analytics dashboards that can automatically detect patterns of physics misconceptions and support micro-learning through embedded interactive video quizzes to prevent passive viewing. Looking ahead, the research agenda for 2026–2030 should focus on testing Multimodal Learning Analytics (MMLA) that combines LMS log data with physiological data (such as eye-tracking) during complex physics problem-solving and developing conceptual frameworks that integrate Generative AI as an adaptive tutor within flipped-classroom LMS environments to facilitate the understanding of physics concepts.

CONCLUSION

Fundamental Findings: from this bibliometric study of 239 Scopus documents (2020–2025) indicate that research on Learning Management System (LMS)-based flipped classrooms in physics education exhibits substantial scientific impact (2,872 citations, h-index 24), with a thematic evolution shifting from emergency adaptation (2020–2021) toward learning analytics, critical thinking, and self-regulated learning (2024–2025), where a full convergence among LMS analytical features, flipped pedagogy, and physics content remains under-explored. **Implication:** These findings reposition the LMS from a passive repository to a substantive, data-driven environment within Physics Education Research frameworks (such as Cognitive Load Theory, JiTT, and TPACK), while practically guiding educators to design pre-class diagnostic quizzes and PhET simulations to optimize face-to-face time for addressing misconceptions. **Limitations:** Its reliance on the Scopus database (2020–2025) and its focus on quantitative-visual mapping, without direct classroom instructional effectiveness measurements or causal-link evaluations. F**uture Research:** Should test AI-driven Adaptive Learning Analytics to detect physics misconceptions in real time, implement Multimodal Learning Analytics (MMLA), and integrate Generative AI as adaptive tutors in flipped classrooms.

AUTHOR CONTRIBUTIONS

Panji Putra Islamaulana developed the conceptual framework, managed the project, drafted the initial manuscript, and validated the overall research structure. **Rahmatta Thoriq Lintangesukmanjaya** performed the bibliometric data extraction, managed references, executed the software mapping, and contributed to drafting the manuscript. **Dwikoranto** designed the analytical methodology, conducted the data analysis, interpreted the bibliometric trends, and critically revised the manuscript. **Neisya Azaria Adinda Putri** verified the retrieved data, refined the analytical framework, and evaluated the quality of the selected documents. All authors reviewed, revised, and approved the final version of the manuscript prior to submission.

CONFLICT OF INTEREST STATEMENT

The authors confirm that there are no conflicts of interest, either financial or personal, that may have influenced the content or outcome of this study.

ETHICAL COMPLIANCE STATEMENT

This manuscript complies with research and publication ethics. The authors affirm that the work is original, conducted with academic integrity, and free from any unethical practices, including plagiarism.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The author used AI-assisted tools solely for language editing, grammar correction, and improving sentence clarity. All ideas, research design, analysis, and academic arguments were developed by the author. All AI-assisted suggestions were carefully reviewed and revised by the author, who retains full responsibility for the content and integrity of this manuscript.

REFERENCES

Adnan, M., & Anwar, K. (2020). Online learning amid the COVID-19 pandemic: Students' perspectives. *Journal of Pedagogical Sociology and Psychology*, *2*(1), 45–51. https://doi.org/10.33902/JPSP.2020261309

Agusta, F., Zuniari, N. I., Kuswanto, H., Siswanto, P., Husna, N., & Nurohman, S. (2025). Bibliometric analysis of flipped classroom trends in physics education: Insights from the Scopus database. *Momentum: Physics Education Journal*, *9*(1), 173–186. https://doi.org/10.21067/mpej.v9i1.10261

Al-Fraihat, D., Joy, M., Masa'deh, R., & Sinclair, J. (2020). Evaluating e-learning systems' success: An empirical study. *Computers in Human Behavior*, *102*, 67. https://doi.org/10.1016/j.chb.2019.08.004

Al-Samarraie, H., Shamsuddin, A., & Alzahrani, A. I. (2020). A flipped classroom model in higher education: A review of the evidence across disciplines. *Educational*

Technology Research and Development, *68*(3), 1017–1051. https://doi.org/10.1007/s11423-019-09718-8

Baig, M. I., & Yadegaridehkordi, E. (2023). Flipped classroom in higher education: A systematic literature review and research challenges. *International Journal of Educational Technology in Higher Education*, *20*, 61. https://doi.org/10.1186/s41239-023-00430-5

Birgili, B., Seggie, F. N., & Oğuz, E. (2021). The trends and outcomes of flipped learning research between 2012 and 2018: A descriptive content analysis. *Journal of Computers in Education*, *8*(3), 365–394. https://doi.org/10.1007/s40692-021-00183-y

Bitzenbauer, P., & Hennig, F. (2023). Flipped classroom in physics teacher education: (How) can students' expectations be met? *Frontiers in Education*, *8*, 1194963. https://doi.org/10.3389/feduc.2023.1194963

Bond, M., Bedenlier, S., Marín, V. I., & Händel, M. (2021). Emergency remote teaching in higher education: Mapping the first global online semester. *International Journal of Educational Technology in Higher Education*, *18*, 50. https://doi.org/10.1186/s41239-021-00282-x

Bredow, C. A., Roehling, P. V., Knorp, A. J., & Sweet, A. M. (2021). To flip or not to flip? A meta-analysis of the efficacy of flipped learning in higher education. *Review of Educational Research*, *91*(6), 878–918. https://doi.org/10.3102/00346543211019122

Camargo, C. P., Tempski, P. Z., Busnardo, F. F., de Arruda Martins, M., & Gemperli, R. (2020). Online learning and COVID-19: A meta-synthesis analysis. *Clinics*, *75*, e2286. https://doi.org/10.6061/clinics/2020/e2286

Castro Benavides, L. M., Tamayo Arias, J. A., Arango Serna, M. D., Branch Bedoya, J. W., & Burgos, D. (2020). Digital transformation in higher education institutions: A systematic literature review. *Sensors*, *20*(11), 3291. https://doi.org/10.3390/s20113291

Cevikbas, M., & Kaiser, G. (2022). Promoting personalised learning in flipped classrooms: A systematic review study. *Sustainability*, *14*(18), Article 11393. https://doi.org/10.3390/su141811393

Dawana, I. R., Setyarsih, W., Suprapto, N., & Dwikoranto. (2022). The effectiveness of virtual class-based e-learning with video-assisted Google Classroom as a physics learning media (2016–2020). *Momentum: Physics Education Journal, 6*(2), 188–198. https://doi.org/10.21067/mpej.v6i2.5849

Del Arco, I., Mercadé-Melé, P., Ramos-Pla, A., & Flores-Alarcia, O. (2022). Bibliometric analysis of the flipped classroom pedagogical model: Trends and strategic lines of study. *Frontiers in Education*, *7*, 1022295. https://doi.org/10.3389/feduc.2022.1022295

Divjak, B., Rienties, B., Iniesto, F., Vondra, P., & Žižak, M. (2022). Flipped classrooms in higher education during the COVID-19 pandemic: Findings and recommendations for future research. *International Journal of Educational Technology in Higher Education*, *19*, 9. https://doi.org/10.1186/s41239-021-00316-4

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Dwikoranto, S., W. A., K., B., D., I. R., & Bergsma, L. N. (2023). Utilisation of universities' massive open online courses in learning management systems: Research trends and bibliometric analysis. *IJORER: International Journal of Recent Educational Research*, *4*(3), 383–398. https://doi.org/10.46245/ijorer.v4i3.380

Ekici, M. (2021). A systematic review of gamification in flipped learning. *Education and Information Technologies*, *26*(3), 3327–3346. https://doi.org/10.1007/s10639-020-10394-y

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Fung, C.-H. (2020). How does flipping classroom foster the STEM education: A case study of the FPD model. *Technology, Knowledge and Learning*, *25*(3), 479–507. https://doi.org/10.1007/s10758-020-09443-9

Gamage, S. H. P. W., Ayres, J. R., & Behrend, M. B. (2022). A systematic review of trends in Moodle use for teaching and learning. *International Journal of STEM Education*, *9*, 9. https://doi.org/10.1186/s40594-021-00323-x

Gómez-Tejedor, J. A., Vidaurre, A., Tort-Ausina, I., Molina-Mateo, J., Serrano, M.-A., Meseguer-Dueñas, J. M., Martínez Sala, R. M., Quiles, S., & Riera, J. (2020). Effectiveness of flip teaching on engineering students' performance in the physics lab. *Computers & Education*, *144*, 103708. https://doi.org/10.1016/j.compedu.2019.103708

Gong, J., Cai, S., & Cheng, M. (2024). Exploring the effectiveness of the flipped classroom on STEM student achievement: A meta-analysis. *Technology, Knowledge and Learning*, *29*(2), 1129–1150. https://doi.org/10.1007/s10758-023-09700-7

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, *3*, 275–285. https://doi.org/10.1016/j.susoc.2022.05.004

Han, S. (2022). Flipped classroom: Challenges and benefits of using social media in English language teaching and learning. *Frontiers in Psychology*, *13*, 996294. https://doi.org/10.3389/fpsyg.2022.996294

Hew, K. F., & Lo, C. K. (2018). Flipped classroom improves student learning in health professions education: A meta-analysis. *BMC Medical Education*, *18*, 38. https://doi.org/10.1186/s12909-018-1144-z

Hew, K. F., Jia, C., Gonda, D. E., & Bai, S. (2020). Transitioning to the "new normal" of learning in unpredictable times: Pedagogical practices and learning performance in fully online flipped classrooms. *International Journal of Educational Technology in Higher Education*, *17*, 57. https://doi.org/10.1186/s41239-020-00234-x

Hew, K. F., Bai, S., Huang, W., Dawson, P., Du, J., Huang, G., Jia, C., & Thankrit, K. (2021). On the use of flipped classroom across various disciplines: Insights from a second-order meta-analysis. *Australasian Journal of Educational Technology*, *37*(2), 132–151. https://doi.org/10.14742/ajet.6475

Huang, A. Y. Q., Lu, O. H. T., & Yang, S. J. H. (2023). Effects of artificial intelligence–enabled personalised recommendations on learners' learning engagement, motivation, and outcomes in a flipped classroom. *Computers & Education*, *194*, 104684. https://doi.org/10.1016/j.compedu.2022.104684

Hung, H.-C., & Young, S. S.-C. (2021). Unbundling teaching and learning in a flipped thermal physics classroom in higher education powered by emerging innovative technology. *Australasian Journal of Educational Technology*, *37*(4), 89–99. https://doi.org/10.14742/ajet.6059

Idsardi, R., Friedly, I., Mancinelli, J., Usai, N., & Matos, L. F. (2023). Outcomes of early adopters implementing the flipped classroom approach in undergraduate STEM courses. *Journal of Science Education and Technology*, *32*(5), 655–670. https://doi.org/10.1007/s10956-023-10066-9

Julia, J., Afrianti, N., Soomro, K. A., Supriyadi, T., Dolifah, D., Isrokatun, I., Erhamwilda, E., & Ningrum, D. (2020). Flipped classroom educational model (2010–2019): A bibliometric study. *European Journal of Educational Research*, *9*(4), 1377–1392. https://doi.org/10.12973/eu-jer.9.4.1377

Kapur, M., Hattie, J., Grossman, I., & Sinha, T. (2022). Fail, flip, fix, and feed—Rethinking flipped learning: A review of meta-analyses and a subsequent meta-analysis. *Frontiers in Education*, *7*, 956416. https://doi.org/10.3389/feduc.2022.956416

Karabatak, S., & Polat, H. (2020). The effects of the flipped classroom model designed according to the ARCS motivation strategies on the students' motivation and academic achievement levels. *Education and Information Technologies*, *25*(3), 1475–1495. https://doi.org/10.1007/s10639-019-09985-1

Klein, P., Ivanjek, L., Dahlkemper, M. N., Jeličić, K., Geyer, M.-A., Küchemann, S., & Susac, A. (2021). Studying physics during the COVID-19 pandemic: Student assessments of learning achievement, perceived effectiveness of online recitations, and online laboratories. *Physical Review Physics Education Research*, *17*(1), 010117. https://doi.org/10.1103/PhysRevPhysEducRes.17.010117

Kushairi, N., & Ahmi, A. (2021). Flipped classroom in the second decade of the Millennium: A bibliometric analysis using Lotka's law. *Education and Information Technologies*, *26*(4), 4401–4431. https://doi.org/10.1007/s10639-021-10457-8

Lintangesukmanjaya, R. T., Mahendra, A., Anugrah, S., Prahani, B. K., Dwikoranto, S. M., & Rizki, I. A. (2024). An EFA analysis of digital technology teaching materials in improving students' critical thinking in physics learning. *JPPS (Jurnal Penelitian Pendidikan Sains)*, *14*(1), 23–38. https://doi.org/10.26740/jpps.v14n1.p23-38

Liu, L., Hew, K. F., & Du, J. (2024). Design principles for supporting self-regulated learning in flipped classrooms: A systematic review. *International Journal of Educational Research*, *124*, 102319. https://doi.org/10.1016/j.ijer.2024.102319

Moral-Muñoz, J. A., Herrera-Viedma, E., Santisteban-Espejo, A., & Cobo, M. J. (2020). Software tools for conducting bibliometric analysis in science: An up-to-date review. *El Profesional de la Información*, *29*(1), e290103. https://doi.org/10.3145/epi.2020.ene.03

Mukherjee, D., Lim, W. M., Kumar, S., & Donthu, N. (2022). Guidelines for advancing theory and practice through bibliometric research. *Journal of Business Research*, *148*, 101–115. https://doi.org/10.1016/j.jbusres.2022.04.042

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, *372*, n71. https://doi.org/10.1136/bmj.n71

Shi, Y., Ma, Y., MacLeod, J., & Yang, H. H. (2020). College students' cognitive learning outcomes in flipped classroom instruction: A meta-analysis of the empirical literature. *Journal of Computers in Education*, *7*(1), 79–103. https://doi.org/10.1007/s40692-019-00142-8

Stöhr, C., Demazière, C., & Adawi, T. (2020). The polarising effect of the online flipped classroom. *Computers & Education*, *147*, 103789. https://doi.org/10.1016/j.compedu.2019.103789

Strelan, P., Osborn, A., & Palmer, E. (2020). The flipped classroom: A meta-analysis of effects on student performance across disciplines and education levels. *Educational Research Review*, *30*, 100314. https://doi.org/10.1016/j.edurev.2020.100314

Tang, F., Chen, C., Zhu, Y., Zhai, C., Ji, Y., Lu, Y., ... & Zhang, Y. (2020). Comparison between flipped classroom and lecture-based classroom in nursing education: A systematic review and meta-analysis. *Nurse Education Today*, *95*, 104604. https://doi.org/10.1016/j.nedt.2020.104604

Torres Martín, C., Acal, C., El Homrani, M., & Mingorance Estrada, Á. C. (2021). Impact on the virtual learning environment due to COVID-19. *Sustainability*, *13*(2), 582. https://doi.org/10.3390/su13020582

Torres-Martín, C., Acal, C., El-Homrani, M., & Mingorance-Estrada, Á. C. (2022). Implementation of the flipped classroom and its longitudinal impact on improving academic performance. *Educational Technology Research and Development*, *70*(3), 909–929. https://doi.org/10.1007/s11423-022-10095-y

Tunggyshbay, M., Balta, N., & Admiraal, W. (2023). Flipped classroom strategies and innovative teaching approaches in physics education: A systematic review. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(6), em2283. https://doi.org/10.29333/ejmste/13258

Ustun, A. B., Zhang, K., Karaoğlan-Yilmaz, F. G., & Yilmaz, R. (2023). Learning analytics-based feedback and recommendations in flipped classrooms: An experimental study in higher education. *Journal of Research on Technology in Education*, *55*(5), 841–857. https://doi.org/10.1080/15391523.2022.2040401 van Alten, D. C. D., Phielix, C., Janssen, J., & Kester, L. (2019). Effects of flipping the classroom on learning outcomes and satisfaction: A meta-analysis. *Educational Research Review*, *28*, 100281. https://doi.org/10.1016/j.edurev.2019.05.003

van Alten, D. C. D., Phielix, C., Janssen, J., & Kester, L. (2020). Self-regulated learning support in flipped learning videos enhances learning outcomes. *Computers & Education*, *158*, 104000. https://doi.org/10.1016/j.compedu.2020.104000

Yoon, M., Hill, J., & Kim, D. (2021). Designing supports for promoting self-regulated learning in the flipped classroom. *Journal of Computing in Higher Education*, *33*(2), 398–418. https://doi.org/10.1007/s12528-021-09269-z

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