TEACHING NEWTON'S LAWS OF MOTION: A BIBLIOMETRIC ANALYSIS OF PEDAGOGICAL APPROACHES AND INSTRUCTIONAL STRATEGIES

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ABSTRACT*—This study mapped the pedagogical approaches, instructional strategies, methodological orientations, research themes, and knowledge gaps in the literature on teaching Newton's Laws of Motion. Scopus records published from 2000 to 2026 were retrieved on July 9, 2026, using Title, Abstract, and Keywords fields. After eligibility screening, 763 documents from 297 sources were analyzed through Biblioshiny and VOSviewer. Keyword co-occurrence data showed that conceptual change and conceptual understanding formed the dominant pedagogical orientation (80 occurrences; total link strength [TLS] = 106). Active learning, modeling instruction, collaborative learning, inquiry-based learning, and problem-based learning were also visible. Among instructional strategies, assessment-based or diagnostic instruction had the highest frequency (47), whereas technology-assisted and AI-supported instruction had the strongest network connectivity (TLS = 73). Simulation, problem-solving, and peer instruction were additional central strategies. The keyword structure indicated a field characterized mainly by assessment-driven, intervention-oriented, mixed-methods, and technology-supported research. Important gaps concerned long-term conceptual retention, multidimensional assessment, comparative effectiveness across learner groups, responsible AI integration, and metacognition. The findings indicate that Newtonian mechanics education is increasingly learner-centered, conceptually oriented, and technology-enabled, while emphasizing that bibliometric prominence does not establish instructional effectiveness.*

Keywords—Newton's Laws of Motion; physics education; bibliometric analysis; pedagogical approaches; instructional strategies

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INTRODUCTION

Newton's laws provide the conceptual foundation for explaining force, mass, acceleration, and interaction. Despite their central role in physics, students often retain intuitive but non-Newtonian ideas, such as believing that a continuous force is required to sustain motion or that action–reaction forces act on the same object. The Force Concept Inventory demonstrated that such misconceptions may persist even after conventional instruction [1]. This difficulty has encouraged educators to employ approaches that make learners predict, explain, model, test, discuss, and revise their ideas rather than merely memorize equations.

Research in physics education consistently supports learner-centered instruction. Interactive engagement produces larger conceptual gains in mechanics than traditional lecture methods [2], while active learning improves performance and reduces failure in science, technology, engineering, and mathematics [3]. Modeling instruction organizes learning around constructing and evaluating scientific representations [4]; peer instruction uses conceptual questions and discussion to expose and correct reasoning [5]; and inquiry-based instruction enables learners to use evidence to explain physical relationships [6]. Simulations and other digital tools further allow students to manipulate variables and connect verbal, graphical, mathematical, and visual representations.

However, the literature remains dispersed across educational levels, research designs, technologies, and pedagogical traditions. Individual studies commonly examine one intervention, such as simulation, peer instruction, problem-based learning, or diagnostic assessment, but provide only a partial view of the intellectual structure of the field. A bibliometric synthesis is therefore useful for identifying the approaches and strategies that are most visible, examining how concepts are connected, and locating emerging and underdeveloped themes. The present study aimed to determine: (1) prominent pedagogical approaches; (2) commonly represented instructional strategies; (3) methodological orientations; (4) major themes and trends; and (5) knowledge gaps and future research directions in studies on teaching Newton's Laws of Motion.

Methodology

A descriptive bibliometric design was used to examine publication patterns and conceptual relationships in Newtonian mechanics education. Bibliometric analysis combines performance analysis with science mapping to describe a research domain through bibliographic metadata [7]. Records were retrieved exclusively from Scopus on July 9, 2026. The search covered publications from 2000 to 2026 and used the TITLE-ABS-KEY field with three concept blocks: Newtonian mechanics and force–motion terms; physics or science education terms; and pedagogy, teaching strategy, conceptual change, assessment, active learning, inquiry, modeling, collaboration, simulation, peer instruction, and problem-solving terms. Articles, reviews, and conference papers were included without a language restriction.

Table 1. Search strategy and analytical scope

Criterion	Description
Database/date	Scopus; July 9, 2026
Coverage	2000–2026; actual records 2001–2026
Search field	Title, Abstract, and Keywords (TITLE-ABS-KEY)
Core query	Newton's laws/Newtonian mechanics AND physics education AND pedagogy/teaching strategies
Eligibility	Articles, reviews, and conference papers; 763 records retained; 0 lost during import
Dataset/tools	763 documents; 297 sources; Biblioshiny and VOSviewer
Analyses	Production, collaboration, co-occurrence, thematic mapping, trend topics, approaches, strategies, and gaps

Full bibliographic records and cited references were exported as CSV and imported into Biblioshiny without data loss. Biblioshiny generated indicators for annual production, productive sources, authors, countries, authorship and collaboration, thematic maps, and trend topics [8]. VOSviewer created the keyword co-occurrence network and calculated occurrences and total link strength (TLS), where occurrences indicate keyword frequency, and TLS indicates the strength of a keyword's connections with other terms [9]. Keywords were grouped by conceptual similarity into pedagogical approaches and instructional strategies. The networks and thematic outputs were then interpreted to infer methodological orientations, gaps, and future directions. Because these categories were derived from bibliometric patterns rather than full-text coding of every document, they indicate prominence and association, not causal effectiveness or exact counts of study designs.

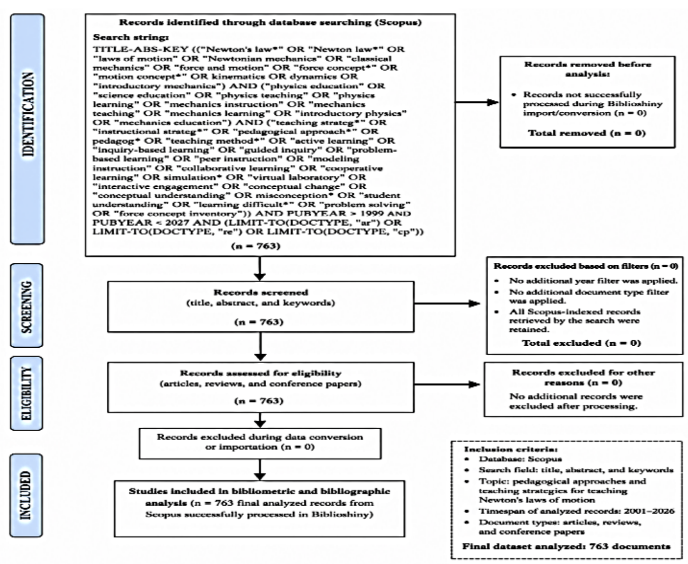

Figure 1. PRISMA flow of data retrieval and selection

RESULTS AND DISCUSSION

Pedagogical Approaches

Conceptual change and conceptual understanding were the most prominent pedagogical orientations, with 80 occurrences and a TLS of 106 (Table 2). Their dominance confirms that misconceived diagnosis and conceptual reconstruction remain central concerns in Newtonian mechanics. Students do not simply lack information; they often possess coherent everyday explanations that conflict with scientific models. Accordingly, effective instruction commonly combines diagnostic questions, cognitive conflict, demonstrations, discussion, simulations, and guided problem-solving to help learners reorganize prior knowledge [10]. The high TLS also shows that conceptual change is closely connected to assessment, active learning, modeling, and technology rather than functioning as an isolated technique.

Active learning ranked second in frequency. It is especially appropriate for Newton's laws because prediction, experimentation, and explanation make students' reasoning visible and revisable. Modeling instruction occurred less often but showed stronger connectivity than active learning, suggesting that models, force diagrams, graphs, vectors, and equations bridge conceptual understanding and problem-solving. Collaborative and inquiry-based approaches were also represented, reflecting the value of social reasoning and evidence-based investigation. Problem-based learning was least visible, although authentic contexts involving transportation, sports, collisions, safety, and engineering can support application. The rankings should therefore be interpreted as research visibility, not as a hierarchy of effectiveness.

Table 2. Prominent pedagogical approaches

Approach	Occ.	TLS	Primary emphasis
Conceptual change/understanding	80	106	Misconceptions and conceptual reconstruction
Active learning	17	16	Student participation and explanation
Modeling instruction	12	23	Scientific models and representations
Collaborative learning	10	13	Shared reasoning and group learning
Inquiry-based learning	6	6	Questioning, investigation, and evidence
Problem-based learning	5	3	Contextualized application

Instructional Strategies and Methodological Orientations

Assessment-based or diagnostic instruction was the most frequent instructional strategy (47 occurrences; TLS = 50). The prominence of assessment, formative assessment, and the Force Concept Inventory indicates that researchers commonly use pretests, posttests, conceptual gains, and standardized instruments to evaluate learning. Such tools are valuable for identifying misconceptions and guiding feedback, but they should be complemented by explanations, observations, laboratory tasks, and performance assessments because a correct multiple-choice response may not reveal the quality of students' reasoning [11].

Technology-assisted and AI-supported instruction had 39 occurrences and the highest strategy-level connectivity (TLS = 73). Educational technology, computational thinking, visual programming, artificial intelligence, large language models, and ChatGPT formed links with simulation, conceptual understanding, and assessment. These tools can support visualization, computational modeling, immediate feedback, and personalized practice; however, prominence is not equivalent to proven effectiveness. Their value depends on scientific accuracy, alignment with learning outcomes, teacher oversight, data protection, and responsible use. Generative AI also introduces risks related to inaccurate explanations, bias, academic integrity, privacy, and overdependence [12; 13].

Simulation-based and immersive instruction was well established (27 occurrences; TLS = 42). Simulations, virtual reality, and augmented reality can make net force, acceleration, friction, and interaction forces observable through vectors, graphs, animations, and manipulable variables. Their effectiveness is strengthened by prediction prompts, structured questions, feedback, and teacher guidance rather than technological novelty alone [14]. Problem-solving remained prominent (24; TLS = 30), emphasizing the application of Newtonian principles to complex situations. Peer instruction appeared less frequently (6; TLS = 12), but its connection with active learning and formative assessment reflects its capacity to elicit explanations and promote revision through discussion.

Table 3. Major instructional strategies

Strategy	Occ.	TLS	Function
Assessment/diagnostic	47	50	Diagnose and monitor understanding
Technology and AI	39	73	Visualization, feedback, and adaptation
Simulation/immersive	27	42	Manipulate and visualize phenomena
Problem-solving	24	30	Apply principles to complex tasks
Peer instruction	6	12	Discuss, justify, and revise ideas

The co-occurrence structure further suggested that quantitative and quasi-experimental orientations were dominant because assessment, formative assessment, conceptual understanding, misconceptions, and the FCI were strongly represented. Design-based and intervention-oriented research was evident in clusters involving active learning, modeling instruction, peer instruction, simulation, virtual reality, and educational technology. The proximity of conceptual assessment, collaboration, conceptual change, and technology also indicated mixed-methods work that combines test results with interviews, observations, discourse, reflections, or usability data [15]. Thus, the field is primarily concerned with evaluating whether instructional interventions work while also examining how students reconstruct their reasoning.

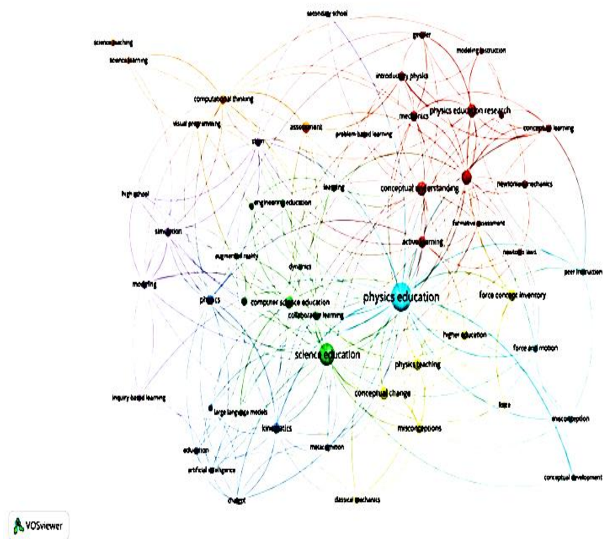

Figure 2. Keyword co-occurrence network of methodological and instructional orientations

Major Themes, Gaps, and Future Directions

Table 4. Major themes, gaps, and research directions

Theme	Knowledge gap	Future direction
Conceptual change	Limited evidence on long-term retention and transfer	Use delayed posttests, interviews, and transfer tasks
Assessment	Heavy reliance on concept inventories	Combine tests with explanations, observation, and performance tasks
Active learning	Few direct concept-specific comparisons	Compare strategies across laws, levels, and learner groups
Technology	Learning effects are less established than usability	Test design features and compare digital, hands-on, and blended modes
Problem-solving	Numerical success may mask weak understanding	Integrate prediction, diagrams, modeling, and reasonableness checks
AI/computation	Emerging evidence and ethical concerns	Evaluate feedback quality, accuracy, privacy, and human oversight
Diversity/metacognition	Learner differences remain peripheral	Examine prior knowledge, confidence, language, and learning difficulties

Seven interconnected themes emerged. First, conceptual understanding and misconception correction remained the intellectual core of the field. Most interventions measure immediate post-instruction gains, while fewer studies examine whether Newtonian concepts are retained and transferred to unfamiliar contexts. Longitudinal studies should therefore include delayed posttests, interviews, and transfer tasks several months after instruction.

Second, assessment-based physics education was highly visible, but reliance on concept inventories may narrow the interpretation of learning. Future studies should combine diagnostic tests with written explanations, free-body diagrams, observations, laboratory performance, problem-solving protocols, and concept maps. Such triangulation can distinguish genuine conceptual understanding from recall, procedural familiarity, or test-taking strategies.

Third, active and student-centered learning represented a broad shift away from lecture-dominated instruction. Yet, the field needs direct comparisons of peer instruction, inquiry, collaboration, modeling, and problem-based learning under similar conditions. Concept-specific analyses are particularly important because inertia, net force, acceleration, and action–reaction pairs present different learning obstacles. Comparative studies across elementary, secondary, and tertiary learners could produce more precise recommendations.

Fourth, technology-enhanced instruction has expanded through simulations, virtual laboratories, augmented and virtual reality, and interactive graphics. Stronger evidence is needed regarding which design features—such as feedback, scaffolding, multiple representations, interactivity, and teacher guidance—produce conceptual mastery and transfer. Studies should compare digital, hands-on, and blended formats and report learning outcomes rather than usability or satisfaction alone.

Fifth, problem-solving remains central, but numerical success does not always indicate conceptual understanding. Novices often select equations from surface features, whereas experts organize solutions around underlying principles [16]. Future instructional models should integrate qualitative prediction, free-body diagrams, conceptual questions, mathematical modeling, computation, and reasonableness checks. Cooperative problem-solving structures may also help students articulate and evaluate their plans [17].

Sixth, computational and AI-supported learning is emerging. Research should compare AI-generated feedback with teacher feedback, evaluate whether AI tutoring improves conceptual learning, and determine whether students can detect inaccurate AI explanations. Clear protocols for transparency, privacy, academic integrity, and human supervision are necessary. AI should function as a supplementary tool rather than a replacement for teachers, experiments, or scientific reasoning.

Finally, learner diversity and metacognition were less central in the network. Future studies should examine how prior knowledge, mathematical preparation, confidence, language, gender-related participation, learning difficulties, feedback, self-efficacy, and metacognitive monitoring affect conceptual change. Treating learners as a uniform group may conceal which scaffolds and representations are most effective for particular populations.

Implications for Teaching and Curriculum

The mapped relationships support an integrated rather than single-method approach to Newtonian mechanics. A practical instructional sequence may begin with diagnostic questions or the FCI to identify prior conceptions, followed by prediction and discussion tasks that create productive conflict between intuitive and Newtonian explanations. Modeling activities can then connect verbal reasoning with free-body diagrams, motion graphs, vectors, and equations. Simulations or hands-on investigations should allow students to manipulate force, mass, friction, and acceleration, while structured problem-solving tasks require them to explain assumptions, select principles, calculate, and evaluate whether an answer is physically reasonable. Peer discussion and formative feedback can be embedded throughout the sequence.

For curriculum designers, the findings suggest that technology should be selected according to conceptual purpose rather than novelty. Digital tools are most defensible when they reveal otherwise invisible relationships, support multiple representations, provide timely feedback, or enable safe and repeatable experimentation. AI-supported tools should include teacher review, transparent use policies, verification of scientific explanations, and activities that require students to critique rather than merely accept generated responses. Assessment plans should likewise extend beyond achievement tests to include explanation quality, model construction, laboratory performance, transfer, and metacognitive reflection.

Limitations

The study has several limitations. First, the dataset was obtained only from Scopus; relevant publications indexed elsewhere or reported in books, theses, and local journals may therefore be absent. Second, the results depend on the search terms, indexing practices, and author-supplied keywords. Terminological variation may cause conceptually similar approaches to appear under different labels, while broad terms such as mechanics or dynamics may retrieve studies in which Newton’s laws are not the primary focus. Third, the categories were inferred from bibliometric networks and representative keywords rather than from a complete full-text coding of all 763 documents. Occurrence and TLS values consequently indicate visibility and connectivity, not instructional quality, effect size, or causal superiority. Finally, the 2000–2026 coverage provides a contemporary view but may underrepresent earlier foundational work. These limitations should guide cautious interpretation and encourage future systematic reviews or meta-analyses that evaluate study quality and learning effects directly.

CONCLUSION

The bibliometric analysis shows that research on teaching Newton’s Laws of Motion is organized primarily around conceptual change, conceptual understanding, learner-centered pedagogy, diagnostic assessment, and increasingly technology-supported instruction. Conceptual change had the strongest pedagogical prominence, while technology-assisted and AI-supported instruction had the strongest strategy-level connectivity. Simulation, problem-solving, peer instruction, active learning, modeling, collaboration, and inquiry function as complementary elements of a broader effort to make students' reasoning visible and scientifically coherent. The literature is mainly assessment-driven and intervention-oriented, with growing mixed-methods and digital dimensions. Future work should prioritize long-term retention, multidimensional assessment, comparative effectiveness, conceptual problem-solving integration, responsible AI, learner diversity, and metacognition. These directions can support more precise, inclusive, and evidence-informed instruction in Newtonian mechanics.

Based on these findings, educators are encouraged to adopt learner-centered, conceptually focused, and technology-enhanced instructional strategies that promote deeper conceptual understanding of Newton's Laws of Motion. Researchers are likewise encouraged to conduct longitudinal, comparative, and evidence-based studies that examine the effectiveness of these approaches across diverse learning contexts to further strengthen physics education.

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