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Research on the Reform of College Physics Teaching in the Context of Digitalization

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Abstract

Drawing on educational philosophy and the learning sciences, this paper offers a systematic analysis of the fundamental predicaments confronting college physics in the digital era. It identifies prominent issues in conventional instruction: a rigid conception of knowledge, monolithic teacher-student relations, inert learning environments, and misaligned assessment systems. In response, the paper advocates a paradigm shift across four dimensions—knowledge production, instructional goals, teacher-student relationships, and learning environments—and outlines an intelligent teaching system composed of mutually reinforcing ecologies for resources, models, assessment, and enabling supports. Addressing core challenges such as the technology paradox, cognitive load, teacher role transformation, and educational equity, the study proposes targeted strategies. It argues that digital reform is not a mere technological upgrade but a reconstruction of educational first principles, aiming to build a learner-centered, technology-empowered ecosystem for intelligent education and to lay the groundwork for cultivating innovative talent.

Keywords

college physics, teaching reform, digitalization, educational ecology, blended learning

1. Introduction

With the rapid advance of information technologies, digitalization is reshaping the ecology of higher education. As a cornerstone of science and engineering education, college physics faces unprecedented opportunities and challenges. Traditional instructional models no longer meet the talent-development needs of the digital era, making reform imperative. In this context, reform transcends upgrades to tools and methods; it entails a systemic transformation of epistemic beliefs, instructional relationships, learning environments, and assessment systems.

As a foundational course, college physics directly influences students' scientific literacy and capacity for innovation. Yet practice reveals persistent problems: a disjunction between knowledge transmission and real-world application, single-track pedagogy, and low learner engagement. Surveys show that more than half of students view college physics as "hard to learn and only partially understood," underscoring the limits of traditional approaches. Meanwhile, digital technologies create new possibilities. How to harness them effectively to drive substantive change in college physics has become a shared concern of researchers and frontline instructors.

Drawing on educational philosophy, the learning sciences, and the philosophy of technology, this study analyzes the deep-rooted difficulties of college physics under digitalization, explores pathways for technology-enabled paradigm change, proposes a system-level blueprint for an intelligent teaching ecology, and addresses the core challenges encountered during reform. The goal is to provide theoretical guidance and practical references to improve educational quality comprehensively and to cultivate innovative talent suited to the demands of the new era.

2. Analysis of the Deep-Seated Predicaments of College Physics Teaching in the Context of Digitalization

The infusion of digital technologies is not a superficial overlay on traditional instruction; it functions like an X-ray that reveals—and often magnifies—long-standing structural contradictions and latent tensions. These predicaments appear across four interrelated dimensions: epistemic views of knowledge, instructional relationships, learning environments, and assessment systems.

Conventional college physics remains anchored in a modernist conception of knowledge—objective, universal, and value-neutral—with teaching defined primarily as efficient, accurate transmission. This orientation produces a linear loop of "concepts–formulae–exercises," severing knowledge from real-world complexity and students' diverse cognitive experiences. Survey data indicate that 53.6% of students find college physics "hard to learn and only partially understood," reflecting the consequences of this epistemic misalignment. Once knowledge is detached from the contexts of its generation and application, it devolves into abstract symbols. Ideally, digitalization should catalyze a post-modern turn toward contextualized, constructive, distributed, and dynamically generated knowledge. In practice, however, polished slide decks and abundant videos frequently perpetuate the old model of "electronic transmission," leaving deeper epistemic change unrealized.

The traditional "teacher-centered, classroom-centered, textbook-centered" triad forms an iron triangle of instructional relations. Digital technologies are inherently decentering: they dissolve spatiotemporal constraints, offer abundant alternative resources, and enable pluralistic interaction. In principle, they can deconstruct absolute authority and move teacher–student relations toward dialogic equality, collaborative inquiry, and shared growth. In practice, technology is often "domesticated": teachers act as anchors or playback operators for online content, students become passive viewers, and "pseudo-interaction" results. The crux is whether teachers can shift from "knowledge authority" to facilitators of learning processes, curators of resources, and moderators of deep dialogue—and whether students can move from passive consumers to active explorers, critical evaluators, and collaborative contributors. Such role changes entail shifts in power and mutual adaptation pressures.

Physics classrooms have long exhibited "inertia": fixed time-space, habitual routines, uniform pacing, and standardized evaluation. Digital technologies sketch a blueprint for environments that are flexible, open, personalized, and collaborative. Virtual labs transcend equipment constraints (Wang Liguang et al., 2005); for example, Li Bin (2025) employs virtual simulation laboratories in experimental-teaching reform to overcome time-space limits. Online collaboration platforms support cross-group, cross-class, and even cross-institutional projects. Adaptive systems attempt individualized pathways (Jin Danqing, 2015). Surveys show that 44.7% of students favor blended models combining in-person and online learning (Zhu Weili et al., 2021), echoing conclusions from experimental-teaching reform and revealing fatigue with single-track environments. Realizing this blueprint requires breaking entrenched "classroom inertia" and "campus boundaries," touching institutional governance, spatial design, and evaluative culture. For instance: How should we evaluate a student who is an active inquirer online but taciturn in person? How do we support "slow-burn" learners who need more time to learn deeply with digital resources? When learning is decoupled from fixed time and place, do "school" and "classroom" need to be reconceived? These are not mere platform questions but matters of ecological and cultural transformation. However, building such a blueprint requires breaking deeply entrenched "classroom inertia" and "campus boundaries," touching upon institutional management, ideas about spatial design, and the guiding orientations of assessment culture. For example, how should we evaluate a student who is an active inquirer online but taciturn offline? How can we provide time and space for "slow-burn" learners who rely on digital resources for deep learning? When learning can occur anytime and anywhere, do the notions of "school" and "classroom" need to be reconstructed? This is not merely a matter of platform construction but a profound challenge to the cultural reshaping of the entire educational ecology.

Traditional assessment systems—dominated by paper-and-pencil tests—support the "transmission–reception" model. They measure memory and computation well but struggle to capture competencies prioritized in digital contexts: complex problem solving, physical modeling, experimental design and data analysis, critical thinking, communication and collaboration, and innovation. Some pilots explore "multi-dimensional assessment" (class participation, online quizzes, design tasks, lab reports) (Li Bin, 2025) and process-oriented evaluation (Wang Liguang et al., 2005). Yet key questions persist: To what extent do these assessments validly reflect complex abilities? How reliable are they? How can results inform teaching and support student development? As learning relies more on digital tools and online collaboration, how can we design assessments that embody competency requirements while remaining understandable and acceptable to stakeholders? The misalignment between assessment and competency goals is a fundamental impediment to deeper reform.

3. Paradigm Shift in College Physics Teaching Driven by Digitalization

Given the depth of these challenges, reform cannot be piecemeal; it requires a system-level paradigm shift—philosophical, methodological, and practical. Past efforts often focused on “using technology to do something” (e.g., replacing blackboards with slides or adding MOOCs), remaining at the level of instrumental rationality. A true paradigm shift reconfigures the underlying logic of the entire instructional system.

College physics must move from “textbook/teacher as sole authority” to open, distributed, collaborative knowledge networks. Knowledge extends beyond textbooks and lectures to research frontiers (e.g., preprint repositories), industrial applications (e.g., virtual labs demonstrating quantum tunneling in chips), and student-generated explanations (blogs, videos). Teachers serve as nodes and connectors, guiding students to build understanding within a rich knowledge ecology.

Instructional objectives must shift from “mastering static content” to developing core literacy and practical wisdom. Core goals include cultivating scientific habits of mind (model building, evidence-based reasoning, constructive skepticism), solving complex engineering/scientific problems, communicating and collaborating effectively, and exercising metacognition for technology-enabled self-directed learning. Physics becomes a vehicle for these capacities rather than the end in itself, prompting teachers to design courses from the question “What capabilities should students develop?” rather than “What content must be covered?”

Instructional relationships must shift from linear, teacher-controlled transmission to learner-centered, networked co-learning. Teacher roles diversify and flatten: designers of learning situations, facilitators of deep dialogue, and technology-enabled partners. Students gain agency and choice, assuming responsibility in exploratory learning. This reconstruction changes classroom power structures and redefines teaching and learning as joint meaning-making.

Learning environments must evolve from a single physical classroom to a fused physical-virtual-social ecology. Learning occurs in classrooms, on platforms, in virtual labs, at project sites, within communities, and at home. The environment is seamlessly connected, data-aware, adaptively intelligent, and supportive of varied interaction. The “walls” of the classroom blur under digital penetration, requiring a rethinking of space, time allocation, resource organization, and activity design to provide open, flexible, and personalized experiences.

Such transformation is gradual and contingent on aligned changes in educational beliefs, instructional practice, and institutional context. Technology is pivotal yet not determinative; purposeful, principle-guided use is essential for meaningful change.

4. Building a New Intelligent Teaching Ecology for College Physics

Supporting this paradigm shift requires a comprehensive ecology—a multi-dimensional, multi-level systems project comprising resource, model, assessment, and support ecologies.

A three-tier resource system—“foundation–extension–tools”—should be established. The foundation consists of high-quality, modularized MOOC/SPOC clusters covering core content (Zhang Rui et al., 2019). The extension provides rich, contextualized, visualized, frontier resources (e.g., high-fidelity simulation libraries, engineering case banks, and history-of-physics materials that cultivate scientific spirit) to spark interest and link applications. The tools tier includes robust online experimentation platforms (for virtual setups, data acquisition/analysis, and iterative design), collaboration tools (co-editing, mind-mapping, project management), and creative tools (for student-produced explanatory videos, research reports, and simple simulations). Resource construction should be open, reusable, and adaptable, forming a dynamic pool for diverse learners.

Deeply integrated, flexibly adaptable pedagogies should be normalized. The flipped classroom must move beyond information delivery to inquiry anchored in challenging problems. Pre-class “cognitive conflict packs” frame real-world scenarios and essential resources; in class, higher-order activities (modeling, debate, design, validation) center on core problems. CDIO can be digitally extended across the full “conceive–design–implement–operate” lifecycle (Wang Liguang et al. 2005), leveraging tools for complex project planning, convenient simulation and iteration, and broad collaboration. Blended project-based learning (PBL) should combine online resource learning, in-person group seminars, and authentic/virtual project practice to realize learning by doing. The essence is integration—not mere aggregation—using digital affordances to solve problems traditional methods cannot.

A pluralistic, processual, competency- and data-oriented assessment system is essential. Pluralism spans multiple agents (self/peer/teacher/system), formats (reports, presentations, defenses, portfolios, interaction traces), and contents (knowledge comprehension, demonstrated abilities, learning attitudes, collaborative contributions). Process assessment uses learning analytics and observational data for timely, fine-grained diagnostics. Competency-oriented tasks situate performance in complex contexts—for example, explaining an unfamiliar experimental phenomenon, constructing and solving a simplified physical model of an engineering problem, or designing an experiment to test a physical conjecture. Data-driven assessment builds digital learner profiles to personalize feedback and guide teaching reflection and course optimization. Results shift from binary scoring to developmental insights.

Stable operation further depends on organizational and cultural supports. Faculty development should include TPACK-based training and certification, “teaching innovation studios,” and communities of practice; it should encourage translating research outputs into distinctive digital resources and make teaching innovation a core dimension of professional growth. Technical infrastructure should provide stable, high-speed networks and cloud platforms, with embedded educational-technology experts offering one-to-one support and instructional design consulting. Institutional innovation should reform evaluation and incentives so that digital-teaching investment, online-course quality, blended/PBL outcomes, and teaching innovations become core indicators; establish a special fund for college physics teaching reform; and optimize learning spaces for flexible layouts and smart devices.

This ecology is marked by connectivity, adaptability, and emergence. Its subsystems are tightly coupled through data flows and feedback loops, enabling self-adjustment, continuous optimization, and innovative emergence. Building it requires systems thinking and sustained investment but is foundational to deep reform.

5. Core Challenges in Digital Teaching Reform and Response Strategies

Constructing a new ecology for college physics is not a voyage on calm waters; it crosses a digital sea dotted with reefs and rapids. The following core challenges demand attention.

We must guard against the technology paradox—the risk that instrumental rationality eclipses educational value. Powerful tools can foster solutionism and over-reliance: dazzling animations displace rigorous reasoning, information abundance overwhelms critical thought, and instant feedback erodes patience for deep reflection. Classrooms may appear bustling while thinking grows shallow. Moreover, learning analytics and AI tutors depend on opaque algorithms; issues of fairness, transparency, and data privacy loom large. The remedy is purpose-driven adoption that keeps education at the center, coupled with digital-citizenship, algorithmic-awareness, and privacy education for teachers and students.

Balancing cognitive load and instructional pacing is equally challenging. Digital environments offer rich information and interaction yet easily overload cognition. Abundance and multitasking fragment attention and induce shallow processing. While flipped and online models increase autonomy, students lacking self-regulation can feel lost, with diminished outcomes. In blended PBL, pacing varies by person and team, requiring stronger dynamic regulation by teachers. Design should be grounded in the learning sciences—e.g., cognitive load theory and multimedia principles—and supported by learning analytics to identify overload or lagging progress and deliver targeted assistance.

Teacher role transformation is a heavy lift, and support gaps persist. The shift from knowledge authority to learning guide, resource integrator, course designer, technology user, and data analyst increases workload: designing innovative activities, curating resources, engaging online, analyzing data, and sustaining professional learning all add pressure (Li Bin, 2025 and Wang Liguang et al. 2005). Many teachers—especially senior faculty—face TPACK gaps and anxiety about new tools and models. If promotion remains paper-centric, the incentive to invest in instructional innovation is weak. A robust support system is needed: dedicated funds for TPACK training and expert coaching; recognition and rewards for teaching innovation; mentorship programs; cross-disciplinary exchange platforms; and reformed evaluations that credit teaching effort, outcomes, and innovation.

Finally, equity must be balanced with excellence. Digitalization enables personalized deep learning and innovation yet can neglect students with weaker foundations or fewer resources. Those with strong backgrounds and self-discipline thrive, while others risk falling further behind. Excellence often requires flexible, individualized programs that can clash with standardized mass education.

Instructional design and resources must embrace learner diversity through tiered instruction, dynamic scaffolding, and flexible management so every student has an appropriate pathway to growth.

Addressing these challenges requires coordinated action. Education authorities should provide policy support and resource guarantees; institutions should foster cultures and structures that encourage innovation; teachers should commit to sustained learning and practical exploration; students should cultivate self-directed learning and digital literacy; educational-technology enterprises should build products aligned with educational principles; and educational researchers should offer theoretical guidance and empirical support. Only through concerted effort can deep reform of college physics teaching advance in the digital era.

6. Conclusion

The reform of college physics in the context of digitalization is ultimately a philosophical undertaking. It compels a re-examination of the meta-questions “What is knowledge?”, “How does learning occur?”, and “What is the purpose of teaching?” By diagnosing deep-seated predicaments, mapping pathways for paradigm change, constructing an intelligent teaching ecology, and addressing core challenges, this study proposes a systemic framework for transitioning from traditional to digital-intelligent instruction.

The goal is not simply to put courses online or make them “smart,” but to build a new ecology of intelligent college physics education—learner-centered, technology-enabled as a bridge, animating knowledge through inquiry, nurturing wisdom through challenge, and fostering innovation through collaboration. In this ecology, teachers shift from transmitters to guides and facilitators; students from passive recipients to active explorers and creators; classrooms from closed spaces of delivery to open platforms for inquiry and collaboration; and assessment from single, result-oriented measures to pluralistic, process-oriented developmental evaluation.

This journey is demanding: we must sustain educational resolve amid technological enthusiasm, uphold the primacy of educating the whole person while renewing tradition, and attend to each learner’s well-being while embracing innovation. It calls for coordinated changes in beliefs, practices, technology adoption, and institutional context, with joint participation by teachers, students, schools, and society.

Future research and practice should focus on the following: (1) deepen research on the regularities of physics learning in digital environments and explore how to use digital technologies to foster students’ deep understanding of physics concepts and modes of thinking; (2) develop more intelligent and personalized learning-support systems to provide precise assistance for students with different starting points and needs; (3) build more scientific and effective evaluation systems that faithfully reflect students’ learning processes and outcomes in digital contexts, and strengthen teachers’ digital-instruction capabilities and establish systematic, continuous mechanisms for professional growth.

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