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Issue Article

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# SCIENTIFIC AND DIDACTIC FOUNDATIONS FOR THE USE OF DIGITAL TECHNOLOGIES AND ARTIFICIAL INTELLIGENCE IN TEACHING PHYSICAL CONSTANTS

***Abstract***: *This article explores the role, efficiency, and didactic integration of modern digital technologies in teaching physical constants. It discusses the application of virtual laboratories, interactive simulations, AI-based learning platforms, and mobile applications in explaining the nature of physical constants and facilitating their practical understanding. Through a comparative analysis with traditional methods, the advantages of modern tools in deepening students' knowledge and enhancing motivation are demonstrated. The results show that digital learning resources significantly aid in conceptualizing physical constants in a clear, accessible, and student-centered manner.*

***Key words***: *physical constants, digital education, artificial intelligence, virtual laboratories, interactive simulations, STEM, mobile applications, personalized learning, physics pedagogy.*
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## Introduction

The 21st-century education system is undergoing a profound transformation, driven by rapid technological advancement. In this context, innovative methodologies are no longer optional but essential. This is particularly true in the teaching of complex scientific concepts such as physical constants, which are not merely numbers or symbols but foundational elements of both natural laws and modern technologies. Their proper understanding is crucial not only for academic achievement but also for nurturing scientifically literate, technologically competent individuals.

As education becomes increasingly digitized, traditional classroom instruction is being supplemented—and in some cases, redefined—by interactive, personalized, and intelligent platforms. This essay explores the scientific and didactic principles underlying the integration of digital technologies and artificial intelligence in the instruction of physical constants, arguing that such integration enhances both the conceptual understanding and the cognitive engagement of learners.

Physical constants—such as the speed of light ($c = 3\times10^8$ m/s), Planck's constant ($h = 6.626\times10^{-34}$ J·s), and the gravitational constant ($G = 6.674\times10^{-11}$ N·m²/kg²)—are immutable parameters that govern the fundamental interactions of the universe. These constants not only underpin major scientific theories, such as relativity and quantum mechanics, but also form the invisible scaffolding of our technological infrastructure. From GPS navigation and MRI scanning to quantum computing and satellite communications, physical constants are deeply embedded in the technologies that define modern life.

In the context of pedagogy, teaching such abstract and mathematically sophisticated concepts has traditionally posed significant challenges. Students often struggle to grasp their significance and practical applications. Thus, there is an urgent need for pedagogical innovations that render these constants more accessible, relatable, and intuitively understandable.

Digital technologies—ranging from virtual laboratories to interactive simulations, AI-powered platforms, and mobile applications—provide powerful tools to overcome traditional barriers in science education. These technologies do not merely serve as supplementary aids; they represent a paradigm shift in the way scientific knowledge is constructed, conveyed, and internalized.

Virtual laboratories, such as those developed by the PhET Interactive Simulations project at the University of Colorado or the Algodoo platform, allow students to conduct simulated experiments in environments where physical resources or safety considerations may limit hands-on experience. These tools facilitate visual and experimental engagement with physical constants, promoting experiential learning even outside the classroom.

Interactive simulations empower students to manipulate variables, observe real-time outcomes, and conduct comparative analyses. These activities foster scientific thinking by encouraging hypothesis formulation, experimental testing, and logical deduction.

Artificial intelligence-based platforms, such as Knewton, Squirrel AI, or Smart Sparrow, analyze students' learning patterns and adapt educational content accordingly. They offer personalized instruction, enabling students to progress at their own pace while receiving real-time feedback.

Mobile applications and gamification techniques—through quizzes, educational games, and scenario-based challenges—present physical constants in a format that resonates with digital-native learners. This approach not only sustains attention but also deepens conceptual retention.

Augmented Reality (AR) and Virtual Reality (VR) integrate abstract concepts into simulated physical environments. For instance, visualizing gravitational forces or Planck-scale phenomena in immersive 3D environments enhances spatial reasoning and fosters a deeper emotional and intellectual connection to the subject matter.

The integration of digital tools into physics education introduces a new layer of didactic sophistication. Compared to traditional methods—which are often instructor-centered and rigid—digital approaches are student-centered, flexible, and dynamic. This difference can be characterized across several dimensions:

**Table 1.**

| Aspect | Traditional Approach | Digital Approach |
|---|---|---|
| Learner Engagement | Passive (lectures, note-taking) | Active (exploration, experimentation, interaction) |
| Experimental Access | Resource-constrained, physical setups | Virtual, safe, repeatable environments |
| Instructional Adaptability | One-size-fits-all lesson plans | Customized, based on real-time learner analytics |
| Accessibility | Limited to physical classroom and schedule | Available anytime, anywhere |
| Feedback Mechanism | Manual and subjective | Automated and objective, in real-time |

These features make digital learning more inclusive, democratized, and equitable, especially in regions where access to laboratory resources is limited.

The use of digital and AI-driven technologies in teaching physical constants yields a number of didactic benefits:

✓ Visualization: Graphical models, animations, and interactive content make invisible forces and abstract relationships more tangible and comprehensible.

✓ Interactivity: Learners actively engage in scientific inquiry by designing experiments, changing parameters, and predicting outcomes.

✓ Adaptability: Lessons can be tailored to individual learning speeds, styles, and cognitive abilities.

✓ Exploration Beyond Physical Constraints: Concepts that are impractical to demonstrate—such as behavior under zero gravity or quantum scale events—can be effectively simulated.

✓ Motivation and Engagement: The integration of game elements, real-world scenarios, and competition increases learners' interest and emotional involvement.

Moreover, these tools enhance metacognitive awareness, allowing students to reflect on their learning strategies and outcomes, thereby developing higher-order thinking skills.

**Conclusion**

Teaching physical constants through digital technologies and artificial intelligence is not merely an instructional upgrade; it represents a pedagogical transformation. By bridging the gap between theoretical abstraction and empirical experience, these tools allow students to internalize complex scientific ideas in more intuitive, meaningful, and applied ways.

In light of this, the digital literacy of educators, their openness to methodological innovation, and their ability to harness emerging technologies are becoming essential attributes of 21st-century teaching. The digital approach to teaching physical constants strengthens interdisciplinary connections, enhances the quality of science education, and prepares learners to be critical thinkers and informed citizens in a scientifically complex world.

Consequently, embedding AI and digital technologies into the teaching of physical constants is not a luxury, but a strategic necessity—one that aligns physics education with the cognitive, technological, and societal demands of our time

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