

Innovative Research on Teaching Mode of Integrating Digital Teaching Resources Into Theoretical Mechanics Classroom

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Abstract: As a core basic course for engineering disciplines, Theoretical Mechanics has long confronted teaching dilemmas including abstract concepts, hard-to-visualize motion processes and complicated mathematical derivations. Targeting the structural contradiction of “difficult-to-teach” and “difficult-to-learn” in traditional classrooms, this paper analyzes the visual-oriented and fragmented cognitive characteristics of students in the digital age and puts forward feasible paths for the integration of digital resources. This research focuses on constructing systematic resources covering dynamic visualization, step-by-step deduction, and virtual-real integrated engineering cases. It also designs a whole-process teaching mode of “pre-class resource preloading and problem-oriented guidance — in-class dynamic demonstration and interactive discussion — after-class virtual simulation and hierarchical expansion”. Practice shows that this mode can effectively resolve difficult knowledge points and improve students’ capabilities in mechanical modeling and engineering analysis. With rigorous logical organization, this paper provides an operable innovative paradigm for classroom reform of Theoretical Mechanics.

Keywords: Theoretical mechanics; Digital teaching resources; Teaching-mode innovation; Dynamic visualization; Virtual simulation

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1. Introduction

Against the background of Emerging Engineering Education construction, Theoretical Mechanics serves as a bridge-building course linking mathematical-physical fundamentals and engineering applications. Its teaching quality exerts a direct influence on the learning of subsequent specialized courses. Nevertheless, traditional blackboard writing and static PPTs can hardly present complex dynamic processes such as relative motion of components and transient changes in constraint forces, which leads to students’ fear-of-learning sentiment and low efficiency of knowledge internalization. With the maturity of information technologies including virtual reality and numerical simulation, digital resources offer new opportunities to address teaching pain points of

“invisible motion, immovable process and inaccurate calculation”^[1]. Based on contemporary college students’ cognitive habits, this paper systematically explores how to deeply integrate digital teaching resources into pre-class, in-class and after-class links of Theoretical Mechanics teaching, aiming to construct a new teaching mode that stimulates internal learning motivation and strengthens engineering thinking.

2. Current teaching situation of theoretical mechanics classroom and digital opportunities

2.1. The “difficult-to-teach” and “difficult-to-learn” dilemma in traditional classrooms

Traditional Theoretical Mechanics classrooms are trapped in two kinds of dilemmas^[2]. From teachers’ perspective, when explaining composite motion of points, they often spend plenty of time drawing transient force diagrams. However, static media can hardly exhibit continuity of motion trajectories and logical evolution of constraints, resulting in a slow classroom rhythm and insufficient delivery of physical meanings. From students’ perspective, during the transition from statics axioms to kinematics analysis, they need to accomplish high-order cognitive transformation from linear-algebra thinking to spatial-geometric imagination. Lacking intuitive perceptions, most students merely memorize formulas mechanically, fail to form logical connections among “motion-force-response”, and are prone to systematic confusion in joint application of general dynamical theorems. This constitutes the driving force for teaching reform^[3].

2.2. Students’ cognitive characteristics and digital-learning demands

Contemporary college students are digital natives. Their information-acquisition approaches feature obvious visualization and interactivity. They have little patience for lengthy blackboard drawing procedures, yet show strong interest in high-precision animations and disassembly of three-dimensional models and can readily accept such content. Chapters in Theoretical Mechanics such as planar motion of rigid bodies and d’Alembert’s principle are well-suited for reducing cognitive load via dynamic visuals^[4]. Students hope to independently control complex physical processes by means of slow-motion playback, review and parameter adjustment, instead of passively receiving result-oriented diagrams. Such updated cognitive requirements drive changes on the teaching-supply side: physical intuitions hidden behind formulas shall be manifested in digital forms, so that students can conduct fragmented learning and in-depth interaction anytime and anywhere. It provides solid audience-psychological foundations for deep integration of information technology and courses.

2.3. Feasibility and entry points for integrating digital resources

At present, the popularization of multi-body dynamics simulation software such as MATLAB and ADAMS, as well as HTML5 animation engines, has removed technical barriers for producing high-precision interactive courseware. Hardware facilities of smart classrooms in most engineering universities can also support high-definition rendering tasks^[5]. The key entry point for integrating digital resources into Theoretical Mechanics shall be precisely oriented toward most-frequently-encountered teaching problems: transforming abstract axiom systems into concrete physical simulations to reshape spatial-imagination capabilities; dividing complicated problem-solving procedures into inference chains with instant feedback to enhance capability of method transfer; upgrading isolated knowledge-point training to virtual-real reconstructed engineering scenarios to cultivate systematic modeling capabilities. Centered on the above goals, a resource library with distinct hierarchies and clear objectives can be established.

3. Systematic construction of digital teaching resources

3.1. Dynamic-visualization resources for abstract concepts

For abstract concepts prone to cognitive bias such as instantaneous center of velocity and Coriolis acceleration, it is necessary to build a working resource library realizing dynamic visualization relying on physical engines^[6]. Such resources are not simple video playback. Instead, different markers are adopted in colors to distinguish convected motion and relative motion; streamer particles are used to display acceleration directions, so as to intuitively present invisible vector fields. When teaching the moment of inertia of rigid bodies, interactive programs can instantly show sensitive changes in dynamical responses caused by variations in mass distribution. Thus, students can get rid of thinking merely dependent on mathematical formulas, form relatively concise physical mental images in their minds, shorten the cognitive distance from conceptual definitions to in-depth understanding, and realize smooth transition between figurative thinking and abstract thinking^[7].

3.2. Step-by-step deduction resources for typical example problems

Solutions for Theoretical Mechanics calculations often require simultaneous solving of dozens of equations. In traditional teaching, teachers and students spend massive amounts of time on copying and checking calculations, which occupies time reserved for studying mechanical mechanisms. Adopting preset digital scripts, step-by-step deduction resources divide typical example problems into logical blocks including object selection, motion analysis, force-modeling, equation formulation and symbolic operation, and set functions of hiding, pausing and fault-tolerant retry^[8]. On mobile-phone terminals, students can advance step by step following prompts. The system automatically checks vector directions and equilibrium conditions of each step. Once errors occur, this step will be locked and relevant concepts will be recalled^[9]. Such scaffolded deduction strictly guarantees the rigor of mechanical analysis, achieves the effect of teaching students in accordance with their aptitude, and greatly increases high-order-thinking components in classrooms^[10].

3.3. Virtual-real integrated resources for engineering cases

To overcome the drawback of disconnection between theory and practice, digital-twin ideas shall be adopted to construct finite-element simulation datasets of real-world equipment, including series-connecting-link stamping mechanisms and gyroscope navigation systems, which are compared with macro slow-motion videos shot on-site. Through data visualization, such resources place stress cloud diagrams under actual working loads side-by-side with theoretical calculation sketches, and directly exhibit errors induced by neglected factors such as friction and elastic deformation^[11]. When students analyze inverse kinematics of excavator buckets, they can adjust telescopic parameters of hydraulic rods in virtual prototypes and observe variations of end-point trajectories. In virtual-real debugging processes, they can experience application scopes of engineering approximation assumptions, and grow into compound-type talents who excel at both theoretical modeling and practical engineering awareness.

4. Innovation of teaching mode integrated into classroom

4.1. Pre-class: Resource preloading and problem-oriented guidance

Before class, cloud-based teaching platforms push animations of key knowledge points and micro-lectures on relevant questions to students. Students watch slow-motion simulations of angular-momentum conservation

at rigid-body collision moments and finish pre-test questions targeting blind-spot knowledge. Based on background data collection, teachers accurately grasp common misconceptions among students concerning impulse-couple concepts and classification of constraint forces, and correspondingly adjust entry points as well as emphasis-and-deemphasis arrangements of face-to-face teaching plans. Static preview is transformed into multi-channel participatory pre-learning via vision, hearing and operation. Students come to class with concrete questions and inquiry interests. On the basis of acquired perceptual cognition, they move forward toward rational construction, which lays solid foundations for in-class flipped learning and in-depth discussions ^[12].

4.2. In-class: Dynamic demonstration and interactive discussion

In classroom-teaching sessions, smart large screens are linked with handheld terminals. When teachers demonstrate composite motion of points for students, they can instantly change moving reference frames to trigger jump-variations of convected-velocity vectors, so as to arouse students' cognitive conflicts regarding relativity of motion decomposition. Targeting such conflicts, group discussions are launched immediately. Students drag parameter sliders on tablet computers to alter convected angular velocities, compare changes in trajectory curvatures, and try to summarize the essence of the velocity-composition theorem. Teachers offer hints for students' speculative misunderstandings and focus on solving problems about selection of moving points and moving reference frames ^[13]. High-density interactive demonstrations transform tedious axiom deduction into visualized logical games, and turn formerly tedious force-analysis classes into thinking-dialogue venues full of scientific-inquiry fun.

4.3. After-class: Virtual simulation and hierarchical expansion

Uniform piles of exercises are not assigned after class. Instead, hierarchical tasks based on virtual-simulation platforms are arranged. At the basic level, students need to complete verification work for kinematic-pair constraint modeling and degree-of-freedom calculation of inverted-pendulum devices. At the advanced level, random wind-load disturbances are added. Students set controller parameters on their own when instability trends emerge and compose analysis reports. Simulation platforms automatically mark underlying calculations, while open-ended designs require manual marking and feedback from teachers ^[14]. Virtual environments provide risk-free trial-and-error conditions for students. Through constant trial-and-error, students convert abstract Theoretical-Mechanics theorems into engineering-oriented judgment and capabilities for solving complex practical problems.

5. Conclusion

For systematic problems existing in Theoretical Mechanics teaching, digital teaching resources are not formal ornaments, but revolutionary forces that reshape teaching structures. The “visualization-deduction-digital-win” three-in-one resource system constructed in this paper, together with whole-process integration modes, effectively mobilizes the enthusiasm of both teachers and students, and enables joint development of students' mechanical intuition and mathematical-logical competence. Against the backdrop of Emerging-Engineering education, it provides powerful guarantees for improving course quality and academic challenge level. Its construction ideas can also be migrated to basic-mechanics course groups, promoting intelligent and targeted development of basic-course teaching and cultivating outstanding engineers with strong modeling capabilities.

Disclosure statement

The author declares no conflict of interest.

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