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Exploration of Textbook Development for Energy Storage Battery Manufacturing Technology from a New Perspective

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Abstract

As the energy transition deepens, energy storage technology plays a crucial role in supporting large-scale renewable energy applications and the construction of new power systems. Its interdisciplinary nature has posed new requirements for higher education. However, due to objective constraints, traditional teaching materials rely on static presentation models and outdated content systems, making them insufficient for the cultivation of talent in the energy storage sector. New-form teaching materials, emerging from the integration of academic development and educational informatization, provide innovative solutions to these challenges through their features such as digital resources, interactive learning environments, and dynamic update mechanisms. Under the context of the new engineering education paradigm and the industry-academia integration needs of energy storage technology, this study analyzes the characteristics of new-form teaching materials, constructs a modular framework covering physical energy storage, electrochemical energy storage, and emerging technologies, and ultimately establishes a multi-dimensional resource system to cultivate innovative talent for societal development.

Keywords

New-form teaching materials; Energy storage technology; Teaching material development.

1. Characteristics of New-Form Teaching Materials

Against the backdrop of digital transformation, teaching content must remain up-to-date. Static texts and images no longer meet students' learning needs, and a single-discipline perspective cannot fully encompass the entire technology chain. This has led to the emergence of new-form teaching materials, characterized by three core aspects, as shown in Table 1.

First, digitalization and interactivity: By breaking the limitations of traditional media, virtual simulation platforms can be used to gradually reproduce the ion migration process in electrochemical energy storage. Three-dimensional modeling can illustrate the stress distribution in flywheel energy storage, making abstract concepts more visually comprehensible. Second, interdisciplinary integration: These materials combine knowledge from materials science, power electronics, thermodynamics, and other disciplines. For example, they reveal the coupling relationship between lithium-ion battery performance and nanomaterial design, fostering systematic thinking for solving complex engineering problems. Third, dynamic openness: To build an educational ecosystem, an online platform can be used for collaborative content development between academia and industry, enabling real-time updates. Emerging technology cases, such as flow batteries, can be incorporated, and user feedback can be utilized to refine knowledge modules, forming a positive feedback loop.

Table 1. Characteristics of New-Form Teaching Materials

Features	Core Description
Digitalization and interactivity	Virtual simulation and dynamic visualization tools are embedded to support interactive exploration of complex principles
Interdisciplinary integration	By breaking disciplinary boundaries and integrating multi-disciplinary knowledge such as electrochemistry, material science, and power engineering, a network knowledge graph is constructed
Dynamic openness	Content modular design, support online update and school-enterprise co-construction, form a closed-loop ecology

2. Necessity of Developing Teaching Materials on Energy Storage Principles and Technology

2.1. Meeting the Development Needs of Energy Storage Technology

As the concept of green development advances, energy storage technologies are also undergoing transformations. The energy density of liquid metal batteries has increased by over 12% annually, while solid-state battery technologies have become highly competitive[1-2]. However, the long revision cycles of traditional textbooks create a generational gap between classroom knowledge and industrial practice. For example, while textbooks still explain graphite anode materials for lithium-ion batteries, enterprises have already adopted silicon-carbon composite technology on a large scale. Similarly, while sodium-ion battery concepts have only recently been introduced in textbooks, China's Zhongke HaiNa has already commissioned a megawatt-hour sodium-ion energy storage station. The outdated nature of textbook content directly affects students' future employment prospects and significantly reduces the effectiveness of talent cultivation. New-form teaching materials, through modular design, can integrate the latest corporate R&D cases and industry data in real-time, forming a comprehensive knowledge graph that aligns with industry trends.

2.2. Addressing the Requirements for Talent Cultivation

Currently, energy storage systems exhibit characteristics of high safety, long lifespan, and low cost, while also increasing in technological complexity. The limitations of a single-disciplinary approach have become apparent. For instance, battery management systems (BMS) require the integration of electrochemical models and intelligent algorithms, and large-scale energy storage stations must coordinate power dispatching and thermal runaway prevention. Currently, 83% of energy storage companies require engineers to possess theoretical knowledge, engineering thinking, and data analysis capabilities. However, traditional textbooks often lead to fragmented knowledge acquisition among students. New-form teaching materials can address this issue by constructing three-dimensional virtual experiment platforms that replicate the grid-connection commissioning process of gigawatt-hour (GWh)-scale energy storage stations[3-5]. Students can adjust power conversion system (PCS) parameters and simulate state-of-charge (SOC) balancing strategies within a digital twin system. Additionally, real industry cases can be incorporated to help students develop a full-cycle understanding, from laboratory validation to industrial implementation.

2.3. Driving Innovation in Teaching Models

In traditional teaching models, instructors dominate the classroom, and students passively receive information. This linear approach makes students feel that current textbooks lack practical guidance and significantly weakens their ability to transfer knowledge. New-form

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teaching materials facilitate a transformation in teaching models through a "flipped classroom + virtual simulation" approach.

Pre-class: Students use an online platform to independently complete electrochemical kinetics model derivations and virtual experiment simulations. The system automatically generates learning analysis reports; During class: Instructors adjust teaching strategies based on real-time data feedback and guide students through the design of energy storage system topologies; Post-class: Students engage in diagnostic training using real industry fault records available in the case study database, thus forming a complete cognitive learning loop.

This approach fosters a more active and engaging learning experience while better preparing students for real-world industry challenges.

3. Design Principles for Teaching Materials on Energy Storage Principles and Technology from the Perspective of New-Form Teaching Materials

3.1. Student-Centered Approach

Given the diverse academic backgrounds and learning needs of students, the standardized delivery model of traditional textbooks struggles to accommodate individualized learning requirements. The abstract nature of electrochemical dynamics and the lack of engineering practice scenarios are major barriers to understanding energy storage principles. New-form teaching materials address this challenge by constructing a “data collection–intelligent analysis–dynamic adaptation” closed-loop system. Before class, students complete online assessments to identify their weak areas. Machine learning algorithms dynamically push customized resource packages, including case studies on energy storage station failures. During the learning process, an interactive platform tracks student progress in real-time, automatically adjusting the difficulty levels of virtual experiments. After completing the assigned tasks, big data analytics generate developmental evaluation reports, creating a spiral learning path. This ensures a truly student-centered approach that meets diverse learning needs and enhances individualized learning experiences.

3.2. Integration of Information Technology

In energy storage education, the static text and images of traditional textbooks fail to illustrate the dynamic processes of battery charging and discharging. Without direct visualization, students often struggle with theoretical comprehension gaps. Virtual simulation platforms, powered by digital twin technology, reconstruct learning environments, allowing students to explore a 3D visualization of lithium-ion battery interiors. They can adjust charge-discharge rates and temperature parameters in real time, observing how lithium ions intercalate within graphite layers and how interfacial side reactions occur. In the flow battery module, students can simulate electrolyte flow rates and optimize electrode structures to explore the balance between energy density and response time[6-7]. Meanwhile, flywheel energy storage experiments allow students to test energy storage efficiency and material stress distribution at different rotational speeds. Additionally, the platform’s built-in machine learning algorithms generate detailed diagnostic reports based on student interactions, recommending relevant academic literature and engineering solutions to enhance their learning experience.

3.3. Keeping Pace with Academic Frontiers

The slow update cycle of traditional textbooks directly affects the pace of talent cultivation. For example, the power capacity of compressed air energy storage (CAES) systems doubles every two years, yet textbook updates take five to eight years, leading to a disconnect between classroom knowledge and industry practices.

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New-form teaching materials solve this issue by establishing dynamic modules that construct a deeply integrated knowledge ecosystem. For instance, in the Jintan Salt Cavern CAES station, a "Technical-Economic Analysis—Policy Impact Assessment—Ethical Risk Consideration" three-dimensional framework is designed to: Guide students in calculating the levelized cost of storage (LCOS), Simulate the impact of different subsidy policies on industry investment return cycles, Assess the ecological footprint of large-scale energy storage station site selection

This industry-academia collaborative case study database is updated quarterly, incorporating cutting-edge developments such as sodium-ion batteries and hydrogen energy storage to cultivate students' multidimensional decision-making skills.

4. Construction of the Content System for Teaching Materials on Energy Storage Principles and Technology from the Perspective of New-Form Teaching Materials

4.1. Physical Energy Storage Technologies

With the ongoing transformation of the global energy structure, physical energy storage technologies have garnered widespread attention due to their efficiency and environmental benefits. Technologies such as pumped hydro storage, compressed air energy storage, and flywheel storage are key representatives in this field, playing crucial roles in power system peak shaving, valley filling, and black start operations. They also provide essential support for the integration and consumption of renewable energy. To facilitate students' in-depth learning of relevant principles and operational mechanisms, 3D animation techniques can be used to visually illustrate energy conversion processes within the system. Additionally, virtual design tasks can be incorporated, such as optimizing the site selection for pumped hydro storage plants. These tasks allow students to deepen their understanding through hands-on practice, significantly improving their learning outcomes, as illustrated in Figure 1. Over time, students experience increased engagement and interactivity, ultimately fostering their practical skills and reinforcing their understanding of physical energy storage technologies.

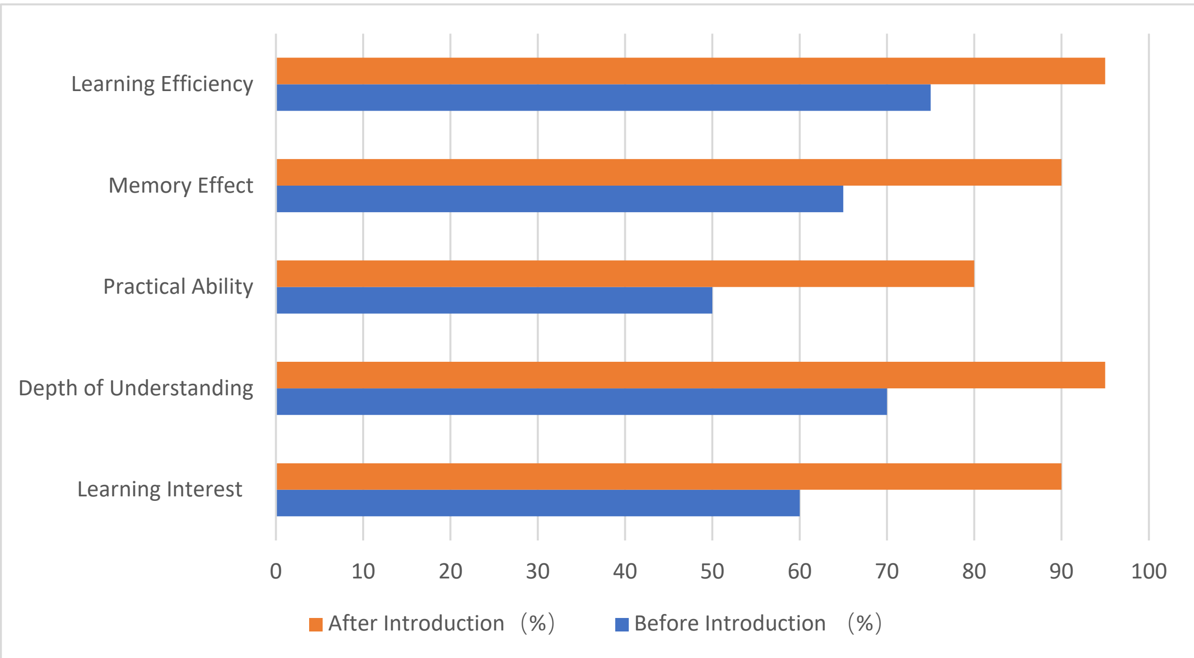

Figure 1. Changes in Student Engagement Before and After the Introduction of 3D Animation Technology

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4.2. Electrochemical Energy Storage Technologies

From the perspective of new-form teaching materials, electrochemical energy storage technology serves as the core content in energy storage principles and technology textbooks. Its content should be deeply analyzed and practically applied in alignment with real-world technological advancements. With the rapid development of electric vehicles and smart grids, lithium-ion batteries, sodium-ion batteries, and flow batteries have become research hotspots due to their high energy density, long cycle life, and environmental friendliness. To ensure that students comprehensively understand battery technologies, educators must go beyond fundamental theories by incorporating simulation experiments on battery management systems (BMS) into the curriculum[8-9]. By simulating real-world operational conditions, students can experience firsthand the complexities of battery management in a virtual environment, preparing them for future careers in energy storage engineering.

5. Practical Development of Teaching Materials for Energy Storage Principles and Technology from the Perspective of New-Form Teaching Materials

5.1. Establishing a Diversified Writing Team

Energy storage technology is characterized by interdisciplinary integration and rapid iteration. Traditional textbook compilation methods often emphasize theoretical depth but lack an engineering perspective. Additionally, training materials independently developed by enterprises tend to be fragmented and fail to provide systematic knowledge. To address these issues, the development of new-form teaching materials can adopt a "government-industry-academia-research-application" collaborative model, forming a writing team composed of university professors, corporate technical directors, and industry association experts.

University teams, leveraging their expertise in electrochemistry and materials science, are responsible for constructing knowledge frameworks for energy storage principles and developing virtual experimental modules. Industry experts contribute insights into policy trends, analyzing how renewable energy consumption policies influence the selection of energy storage technology pathways. This cross-disciplinary approach, structured around modular division of labor, establishes a dynamic update mechanism, effectively bridging the gap between textbook content and industrial demands.

5.2. Developing a Structured Curriculum Framework

When designing the textbook framework, all contributors should conduct thorough preparatory work and adopt an integrated model encompassing principles, technology, engineering, and ethics to ensure strong logical coherence and systematization. This structure allows students to engage deeply with domain knowledge, guiding them in transitioning from theoretical understanding to practical applications and even ethical considerations in technological development.

To achieve this, the textbook can be divided into three major sections: Fundamental Knowledge – Covering core theoretical concepts; Practical Applications – Incorporating case studies, virtual simulations, and engineering projects; Emerging Technologies – Introducing the latest advancements in energy storage.

To further enhance the practicality and richness of the textbook, each chapter can include QR codes linking to supplementary resources, such as technical patents, policy documents, and industry reports. This approach enables students to access real-time updates and interact with diverse learning materials, while also allowing for immediate feedback collection to ensure the timely revision and optimization of teaching content.

5.3. Establishing an Evaluation System for Teaching Materials

The development of energy storage principles and technology teaching materials should prioritize content innovation while ensuring high-quality instruction through a comprehensive evaluation system.

The evaluation framework consists of three key components: Formative Assessment- Tracks students' progress in virtual experiments and evaluates the quality of their online interactions, providing a comprehensive assessment of learning attitudes and engagement; Summative Assessment-Requires students to submit a complete energy storage system design proposal, which undergoes rigorous peer review to assess their theoretical mastery and practical capabilities; Feedback Mechanism-Regularly collects students' opinions on teaching materials, ensuring timely updates to case studies and simulation models, keeping content aligned with industry advancements and technological progress[10].

By integrating these innovative teaching strategies and evaluation mechanisms, new-form teaching materials can effectively support talent cultivation in energy storage technology, ensuring that students acquire both theoretical expertise and engineering problem-solving skills.

Table 2. Advantages of each evaluation system

Evaluation system	Description	Advantages
Process evaluation	Student completion in the virtual experiment as well as the quality of the online interaction were recorded	By recording students 'performance and online interaction in the virtual experiment, students 'learning attitude, enthusiasm and participation can be comprehensively evaluated, which is helpful for teachers to understand students 'learning status in time and give targeted guidance
Achievement evaluation	Students submit energy storage system designs and receive rigorous peer review	By submitting the design scheme of energy storage system and accepting peer review, it can directly test students 'mastery of theoretical knowledge and practical ability, and also help students to learn and communicate with each other
Feedback mechanism	Regularly collect student feedback on the content of the textbook, and update the case base and simulation model in time	By introducing a feedback mechanism to regularly collect students 'opinions and suggestions on the content of the textbook, it can timely find and update the outdated or not in line with the actual needs of the content, to ensure that the textbook can keep pace with The Times and meet the learning needs of students.

6. Conclusion

The development of new-form teaching materials is an inevitable trend in addressing technological innovation. Due to various constraints, traditional textbooks exhibit significant limitations, making it essential to adopt a student-centered approach that integrates a unified teaching resource system. This transformation enhances student initiative, leverages information technology to visualize abstract concepts, and ensures the completeness of knowledge structures through modular content design. A collaborative development model effectively addresses the mismatch between textbook content and industrial requirements, while a dynamic evaluation mechanism ensures timely knowledge updates. Moving forward, the construction of teaching materials for energy storage technology should continue evolving toward a multi-dimensional and interactive format. This approach will cultivate interdisciplinary talent with both theoretical expertise and engineering thinking, ultimately providing sustained intellectual support for technological breakthroughs and industrial upgrades in the energy storage sector, particularly within the context of the renewable energy revolution.

References

[1] Behera, P.K.; Pattnaik, M. Coordinated Power Management of a Laboratory Scale Wind Energy Assisted LVDC Microgrid With Hybrid Energy Storage System. IEEE Trans. Consum. Electron. 2023, 69, 467–477.

[2] Pasupuleti, S.S.; Tummuru, N.R.; Misra, H. Power Management of Hybrid Energy Storage System Based Wireless Charging System With Regenerative Braking Capability. IEEE Trans. Ind. Appl. 2023, 59, 3785–3794.

[3] Liu, X.; Suo, Y.; Zhang, Z.; Song, X.; Zhou, J. A New Model Predictive Current Control Strategy for Hybrid Energy Storage System Considering the SOC of the Supercapacitor. IEEE J. Emerg. Sel. Top. Power Electron. 2022, 11, 325–338.

[4] Roy, P.; He, J.; Liao, Y. Cost Minimization of Battery-Supercapacitor Hybrid Energy Storage for Hourly Dispatching Wind-Solar Hybrid Power System. IEEE Access 2020, 8, 210099–210115.

[5] Fang, J.; Tang, Y.; Li, H.; Li, X. A Battery/Ultracapacitor Hybrid Energy Storage System for Implementing the Power Management of Virtual Synchronous Generators. IEEE Trans. Power Electron. 2017, 33, 2820–2824.

[6] Abadi, S.A.G.K.; Habibi, S.I.; Khalili, T.; Bidram, A. A Model Predictive Control Strategy for Performance Improvement of Hybrid Energy Storage Systems in DC Microgrids. IEEE Access 2022, 10, 25400–25421.

[7] Behera, M.K.; Saikia, L.C. A Novel Resilient Control of Grid-Integrated Solar PV-Hybrid Energy Storage Microgrid for Power Smoothing and Pulse Power Load Accommodation. IEEE Trans. Power Electron. 2022, 38, 3965–3980.

[8] Ravada, B.R.; Tummuru, N.R. Control of a Supercapacitor-Battery-PV Based Stand-Alone DC-Microgrid. IEEE Trans. Energy Convers. 2020, 35, 1268–1277.

[9] Luo, Y.; Fang, S.; Kong, L.; Niu, T.; Liao, R. Dynamic power management of Shipboard Hybrid Energy Storage System under Uncertain Navigation Conditions. IEEE Trans. Transp. Electrification 2023.

[10] Li, J.; Han, Y.; Zhou, S.; Li, Z.; Fan, H.; Wang, B. Improved Linear Active Disturbance Rejection Control with Dynamic Event-triggered Mechanism for Hybrid Energy Storage System. IEEE Trans. Transp. Electrification 2023.