

University Physics Education Under the ETA Pedagogical Framework

ZHAO Xinli, XIE Xinyi

University of Shanghai for Science and Technology, Shanghai, China

The Explore, Transform, and Apply (ETA) pedagogical approach has significantly influenced university-level physics education, reshaping traditional perceptions of teaching and learning. Designed to cultivate scientific reasoning, stimulate innovation, and enhance students' ability to solve complex problems, the ETA method addresses key competencies essential for success in science and technology. As a foundational discipline, physics plays a vital role in developing experimental proficiency, logical thinking, and problem-solving skills. By creating a student-centered learning environment, the ETA methodology inspires learners to explore physical phenomena, transform theoretical understanding into practical capabilities, and deepen their application of core concepts. As a progressive complement to traditional instruction, the ETA framework offers a forward-looking strategy for preparing future physicists and engineers to thrive in a rapidly evolving technological world.

Keywords: ETA teaching method, university physics, scientific thinking, problem-solving skills

Introduction

University education is undergoing a profound transformation driven by the emergence of innovative pedagogical approaches, particularly in Science, Technology, Engineering, and Mathematics disciplines. At the forefront of this transformation is the Explore, Transform, and Apply (ETA) methodology, which harmoniously integrates active student engagement with traditional didactic instruction, injecting renewed vitality into the higher education classroom. As a pioneering model in contemporary educational reform, the ETA approach represents a paradigm shift how knowledge is delivered and absorbed.

ETA fosters a dynamic, multi-dimensional learning environment that emphasizes both the acquisition of theoretical knowledge and its practical application. Central to this approach is a deliberate reorientation of the teaching and learning process toward the active role of the student. Learners are encouraged to engage with unfamiliar concepts through independent inquiry and collaborative problem-solving, promoting the transformation of abstract ideas into meaningful understanding and insight. This process not only supports the internalization of knowledge but also cultivates essential skills through continuous practice, reflection, and real-world application. The implementation of the ETA methodology in university-level physics education is particularly valuable. As a cornerstone subject within science and engineering curricula, the quality of physics instruction plays a pivotal role in shaping students' foundational understanding and their ability to engage with advanced scientific concepts.

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ZHAO Xinli, Ph.D., Lecturer, College of Science, University of Shanghai for Science and Technology, Shanghai, China.

XIE Xinyi, Master, College of Science, University of Shanghai for Science and Technology, Shanghai, China.

Consequently, a comprehensive pedagogical shift is imperative to align physics education with the evolving demands of academic and professional contexts. The integration of ETA offers both impetus and direction for such reform (Prince & Felder, 2006).

Notably, the ETA framework facilitates the seamless transition from theoretical learning to practical competence through its distinctive student-centered design. Its broader adoption in physics instruction holds the potential to substantially enhance teaching effectiveness, enrich student learning outcomes, and equip future physicists and engineers with the critical skills and confidence required to navigate and contribute meaningfully to an increasingly complex and technological world.

The History and Evolution of the ETA Method

The Explore, Transform, and Apply (ETA) pedagogical approach originated from mid-20th century educational reforms that emphasized student-centered learning to foster insight, critical thinking, and creativity. Since then, the model has continuously evolved in response to changing educational paradigms and sociocultural shifts. Its adaptability has enabled widespread international adoption, with China emerging as a prominent advocate of ETA pedagogy, incorporating it into broader national educational reforms. The ETA framework consists of three progressive stages, each with a distinct role in the learning process. The first, exploration, emphasizes curiosity-driven inquiry over direct instruction. Rather than presenting fixed theories, instructors guide students to pose questions, observe phenomena, and engage in investigative activities. Rich multimedia resources—such as animations, videos, experiments, and demonstrations—serve to spark students' enthusiasm and initiate active learning. The second stage, transformation, acts as a bridge between sensory experience and conceptual understanding. In this phase, students analyze and interpret observations through critical thinking and collaborative discussions. The instructor functions as a facilitator, supporting students in constructing logical and coherent conceptual frameworks from their initial explorations. The final stage, application, focuses on transferring learned knowledge to practical contexts. Students apply their understanding of physics to explain real-world phenomena or address authentic problems. This phase not only assesses content mastery but also cultivates problem-solving abilities and innovative thinking—skills essential in science and technology. In China, the implementation of the ETA model in university-level physics teaching reflects a decisive move toward more dynamic and participatory learning. Through curriculum redesign and professional development initiatives, educators have adopted ETA to deepen students' conceptual grasp and promote creative engagement. Crucial to the success of ETA is the integration of comprehensive assessment systems and digital learning tools. Chinese institutions have begun employing diverse evaluation strategies that measure engagement, practical competence, and innovative capacity. Simultaneously, technologies such as virtual labs, simulations, and interactive modules have enhanced the immersive quality of ETA-based instruction. The ETA approach represents a transformative shift in global education—especially in China—toward models that value active engagement, deep understanding, and real-world relevance. By fostering adaptable, creative, and skilled learners, ETA redefines physics education as a process of discovery, reasoning, and application, far beyond passive knowledge acquisition.

The Concept of the ETA Teaching Method

Although the Explore, Transform, and Apply (ETA) method is a relatively recent pedagogical innovation, it is deeply rooted in established educational theories and the long-standing tradition of experiential learning. The foundational concept of experiential learning, central to modern educational psychology (Mu, 2020), can be

traced to the influential work of John Dewey. Over a century ago, Dewey emphasized the necessity of active student engagement in learning and critiqued traditional didactic methods for their overreliance on rote memorization at the expense of critical thinking and practical skill development—concerns that remain relevant today. The ETA methodology represents a contemporary evolution of Dewey’s philosophy. Its three stages encapsulate the teaching-learning process: exploration, where students actively investigate real-world phenomena; transformation, where initial observations are synthesized into systematic understanding; and application, where learners use their acquired knowledge to solve practical problems. This structured progression encourages students to move from curiosity to comprehension and finally to capability. Since its inception, the ETA method has been embraced internationally and refined across diverse educational settings. Its adaptability has supported its expansion into various academic disciplines. However, its application in university-level physics remains relatively limited and emerging (Mu, 2022). The following chapters will explore how ETA can be effectively implemented in physics instruction and will provide a comparative analysis with traditional teaching approaches. The aim is to offer educators actionable insights into the pedagogical strengths and potential challenges of adopting ETA in their classrooms.

The Necessity of the ETA Method in Teaching University Physics

The relevance of the Explore, Transform, and Apply (ETA) pedagogical model in university physics education lies in its ability to foster active student engagement, deepen conceptual understanding, and enhance the application of theoretical knowledge in real-world contexts. This approach marks a significant departure from traditional instructional paradigms. Conventional physics instruction, long dominated by teacher-centered delivery, often results in passive learning. Students may memorize key concepts but struggle to apply them effectively in unfamiliar situations. This limitation highlights the urgent need for a more dynamic and student-centered method, as represented by the ETA framework. At the exploration stage, ETA stimulates curiosity and intrinsic motivation through observation, inquiry, and interactive investigation. Particularly in physics—where abstract concepts often appear daunting—exploration-based learning helps students relate scientific principles to real-life experiences. Experiments and demonstrations at this stage also make these concepts more tangible and accessible. As learning progresses into the transformation phase, students analyze data, interpret phenomena, and derive underlying physical laws. This fosters a shift from passive knowledge reception to active knowledge construction, strengthening their cognitive engagement and theoretical understanding. The application stage culminates the process, requiring students to apply what they’ve learned to solve complex, real-world problems. This not only reinforces theoretical knowledge but also cultivates practical problem-solving abilities essential for scientific and engineering careers. The integration of digital technologies—such as virtual labs and simulation platforms—further enhances the ETA model’s effectiveness. These tools offer greater flexibility, interactivity, and accessibility, aligning well with the needs of a technology-driven educational landscape (Pan, Ye, Chen, & Zheng, 2024). The ETA pedagogy transforms university physics instruction by creating an engaging, exploratory, and application-oriented learning environment. In an era of rapid scientific and technological advancement, its adoption is not merely advantageous but essential.

The Implementation of the ETA Teaching Method in University Physics

The practical implementation of the Explore, Transform, and Apply (ETA) teaching methodology signifies a profound and productive shift from traditional lecture-centered instruction to a dynamic, student-centered

learning paradigm. The following sections provide illustrative examples of how the ETA approach can be effectively integrated into the pedagogical practice of university-level physics education.

Exploration Phase

When introducing a new topic—such as the fundamental principles of electromagnetism—a university physics course can begin with a carefully guided discovery process. In this initial stage, instructors design hands-on experimental activities that offer students their first direct encounter with the intricate interactions between electric charges and magnetic fields. Through active engagement with physical experiments, students transcend the limitations of abstract verbal or mathematical explanations, developing an intuitive and holistic understanding of the subject matter. During this phase, the role of the instructor evolves from that of a traditional lecturer to a facilitator and mentor. Educators provide essential tools and experimental resources, while simultaneously guiding students through the investigative process. They encourage observation, questioning, and critical analysis, thereby cultivating scientific thinking. Additionally, the incorporation of modern technologies—such as computer simulations and virtual labs—enables the visualization of complex physical phenomena in an intuitive and compelling manner. Open-ended discussions and collaborative learning further reinforce students' critical thinking skills and promote a deeper, more interconnected understanding of key concepts.

Transformation Phase

As students accumulate perceptual knowledge and hands-on experience during the exploration phase, they gradually transition into the transformation phase, where intuitive understanding is refined into systematic theoretical knowledge. This stage is marked by structured problem-solving activities designed to deepen students' comprehension and facilitate knowledge transfer across contexts. In this phase, instructors introduce tiered and progressively challenging exercises that require students to apply theoretical concepts in diverse scenarios. Reflection becomes a critical component of learning, as students are encouraged to analyze their thought processes and learning trajectories. Through reflective practices—such as group discussions, research-based assignments, and the writing of learning journals—students explore the intrinsic connections between empirical observations and theoretical frameworks. These activities consolidate their foundational knowledge while simultaneously nurturing their capacity for independent inquiry and analytical problem solving.

Application Phase

The application phase constitutes the culmination of the ETA pedagogical approach, where theoretical learning is translated into practical competence. At this stage, students are tasked with applying their acquired knowledge and skills to address authentic, real-world problems. This may involve designing and constructing basic electrical circuits, conducting experimental investigations, and composing detailed laboratory reports. Such practical engagements provide students with a vivid and concrete experience of the relevance and utility of physics. They witness firsthand how abstract theories and mathematical models inform tangible technological applications and scientific understanding. The act of applying theory to practice not only reinforces conceptual mastery but also fosters a lasting enthusiasm for physics. Furthermore, this experience lays a robust foundation for students' future endeavors in scientific research, engineering innovation, and interdisciplinary problem solving.

An Enhanced Learning Experience With the ETA Method

Compared to traditional lecture-based teaching methods, the Explore, Transform, and Apply (ETA)

pedagogical approach has been effectively integrated into university-level physics instruction, yielding a range of significant advantages.

Active Learning and Increased Engagement

The ETA method fosters an active learning environment in which students take center stage in the educational process. This learner-centered model substantially enhances student engagement, as it shifts the emphasis from passive absorption of information to active exploration and knowledge construction. As a result, students become more deeply involved in their learning journey, which not only enhances their conceptual understanding of physics but also improves knowledge retention and promotes enduring academic outcomes.

Bridging Theory and Practice

A key strength of the ETA approach lies in its capacity to bridge theoretical frameworks with practical applications. Through hands-on experiments and involvement in real-world projects, students are able to contextualize abstract physical principles within tangible experiences (Harlow, 2018). This integration not only makes the study of physics more relevant and accessible, but also allows students to perceive the real-world utility and power of theoretical knowledge. Such experiences invigorate their interest in the subject and fuel a genuine desire for further inquiry.

Development of Critical Thinking and Problem-Solving Skills

The ETA methodology places strong emphasis on cultivating critical thinking and problem-solving abilities—skills that are indispensable for both scientific inquiry and real-world decision-making. By encouraging students to question assumptions, analyze data, and formulate evidence-based conclusions, the ETA method nurtures intellectual independence and cognitive flexibility. These essential competencies, often underemphasized in traditional instruction, provide a strong foundation for academic research, professional development, and lifelong learning.

Enhancement of Collaboration and Communication Skills

In addition, the ETA approach highlights the importance of collaborative learning through group discussions and team-based projects. These activities offer students valuable opportunities to develop their communication and interpersonal skills. Working collaboratively, students practice active listening, articulate their viewpoints, navigate differing opinions, and engage in collective problem solving. These experiences not only prepare students for teamwork-oriented professional environments, but also contribute to their personal growth and overall social competence.

Constructing a University Physics Teaching Model Based on the ETA Method

The development of a university physics teaching model grounded in the Explore, Transform, Apply (ETA) pedagogy signifies a meaningful departure from traditional didactic instruction, expanding both the depth and effectiveness of physics education. In response to the growing recognition of the limitations inherent in conventional lecture-based methods, the ETA framework offers a student-centered, interactive, and inquiry-driven alternative well aligned with contemporary educational needs. In the exploration phase, the goal is to spark students' curiosity and encourage independent inquiry into the complexities of the physical world. The teacher's role shifts from a knowledge transmitter to a designer of thought-provoking questions and a facilitator of hands-on investigation. Through the use of multimedia resources—such as animations, simulations, and live demonstrations—students are motivated to engage actively with physical phenomena, transitioning from passive

reception to proactive discovery (López & Casado, 2019). The transformation phase focuses on deepening understanding and integrating empirical experiences with theoretical frameworks. At this stage, students begin to interpret observed phenomena through scientific reasoning, moving from intuitive perceptions to abstract conceptualization. Teachers support this process by promoting critical thinking, guiding structured group discussions, and designing scaffolded learning activities. Their role becomes one of intellectual mentorship, helping students construct meaningful connections between observation and theory.

The application phase consolidates learning by encouraging students to transfer their knowledge to real-world contexts. Through the completion of experimental tasks, problem-solving exercises, and project-based assignments, students demonstrate their ability to apply physics principles to analyze, explain, or predict complex scenarios. This stage not only reinforces theoretical understanding but also fosters practical competence and creative thinking. Successful implementation of the ETA model requires a high level of pedagogical professionalism. Teachers must be well-versed in the principles and methods of ETA, which necessitates targeted professional development and ongoing instructional training. Equipping educators with the necessary skills ensures they can faithfully apply and adapt the model within diverse teaching contexts. Assessment practices must also evolve to align with the ETA approach. In addition to traditional written exams, diverse evaluation methods—such as performance-based tasks, innovation assessments, and peer collaboration—should be employed to capture the full spectrum of student learning. A robust feedback system is equally essential to guide continuous improvement and support students' cognitive and practical development. Digital technology plays a pivotal role in facilitating the ETA method. From virtual laboratories to interactive simulation tools, digital platforms enhance engagement and allow seamless transitions across the three instructional stages. These tools empower students to explore, transform, and apply knowledge within a dynamic and immersive learning environment. The construction of a university physics teaching model based on the ETA methodology represents a forward-looking reform of traditional pedagogy. By integrating classical instructional values with modern educational innovations, this approach fosters deeper learning, promotes transferable skills, and prepares students for future scientific and technological challenges. The adoption of this model promises to transform physics education into a more meaningful and impactful experience.

Conclusion

The ETA approach embodies a forward-looking, innovative, and holistic framework for the teaching of university-level physics, one that effectively addresses the evolving and diverse learning needs of today's students. By seamlessly integrating foundational physics concepts with practical problem-solving tasks, the ETA methodology not only enhances scientific literacy, but also fosters students' creativity, critical thinking, and the ability to tackle complex, real-world challenges—skills that are indispensable for their future academic and professional endeavors. In light of rapid developments in educational technology and the ongoing evolution of learning sciences, the ETA teaching model holds vast potential for continued refinement and broader application. As educational paradigms shift, learning styles diversify, and the scope of physics applications continues to expand, the ETA approach offers a dynamic and adaptable framework that can evolve in tandem with these trends. This presents a promising vision for the future of physics education—one characterized by interactivity, relevance, and intellectual vitality. The incorporation of innovative pedagogical strategies such as ETA into university physics curricula not only signals a significant pedagogical advancement, but also contributes to the creation of a rich, engaging, and future-oriented educational ecosystem. It empowers students to engage with the frontiers

of scientific inquiry and equips them with the tools to thrive in a rapidly advancing technological world. Thus, the sustained promotion and implementation of the ETA approach is poised to elevate the quality and impact of physics education, enabling students to attain deeper scientific insight and to forge meaningful paths in research, innovation, and beyond.

References

- Harlow, D. (2018). Exploratory learning in physics: Perspectives on practical work. *Journal of Physics: Conference Series*, 1065(3), 1-6.
- López, A. F., & Casado, M. A. (2019). A teaching strategy based on active learning to improve student conceptual understanding of physics. *Physics Education*, 54(6), 1-9.
- Mu, L. (2020). What is ETA physical cognition model. *Physics and Engineering*, 30(1), 29-33.
- Mu, L. (2022). The ETA physics learning method: The analysis and solution of physics learning problems for undergraduate students based on the physical cognition theory. *Physics and Engineering*, 32(5), 5-10, 14.
- Pan, W., Ye, X., Chen, L., & Zheng, H. (2024). Exploring physics experiments teaching mode of strengthening deeper learning and promoting higher order thinking ability. *Physics and Engineering*, 34(2), 46-53.
- Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of Engineering Education*, 95(2), 123-138.