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Research on Applications and Values of 5E Teaching Model in University Physics Education

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Under the current background of educational reform, the teaching model in university is undergoing a profound transformation from teacher-led to student-centered. 5E teaching model, consisted with Engagement, Exploration, Explanation, Elaboration and Evaluation phases, is regarded as an innovative approach of focusing on students' active exploration and knowledge construction, which provides an effective support for the reform of university physics teaching. This research mainly discusses the feasibility of implementation in university physics courses, and analyzes its applications and values from the perspectives of teaching quality and educational objectives. Teaching practice demonstrates that 5E teaching model obviously enhances students' learning interests and cultivates scientific inquiry skills, innovative consciousness and independent thinking abilities, further improving knowledge transfer and comprehensive application skills. Therefore, 5E teaching model has important theoretical significances and practical values for promoting the reform of university physics education, further improving educational quality and cultivating comprehensive innovative talents according with the requirements of the new era.

Keywords: educational reform, student-centered, 5E teaching model, university physics education

Introduction

In the new era context of educational reform, university education model has shifted from teacher-led to student-centered. This educational transformation aims to cultivate high-quality talents with strong comprehensive abilities, broad knowledge horizons and robust innovative awareness, thereby fostering the social responsibility and patriotic sentiment of students (Rafon, 2020). A series of novel pedagogical approaches are proposed in various subject constructions, such as Science, Technology, Engineering, and Mathematics regions. As a fundamental compulsory course for science and engineering, university physics course has attracted amounts of students and played a significant role in stimulating critical thinking and fostering innovation capability (Tural, 2010; Ateko, 2025). Therefore, exploring innovative teaching methods are extremely importance for enhancing the quality of university physics education and cultivating high-level technological talents.

5E teaching model was developed by Biological Sciences Curriculum Study (BSCS) in United States based on constructivist learning theory, which contains five phases: "Engagement, Exploration, Explanation, Elaboration and Evaluation" (Boddy, 2003; Balci, 2006). Importantly, the designed 5E teaching model is suitable for teaching procedures of any subjects. This teaching model emphasizes a student-centered approach, and

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devotes to stimulating the learning interests of students. Therefore, 5E teaching model has garnered extensive attentions from educators in worldwide.

For promoting the reform of university physics course and improving teaching quality, 5E teaching model introduced into university physics course is conductive to facilitate the mastery of disciplinary knowledge and foster the spirit of scientific innovation for students.

The Basic Connotation of 5E Teaching Model

Generally, Engagement, Exploration, Explanation, Elaboration and Evaluation phases all have an initial letter of "E", so this teaching structure is named as "5E teaching model" (Chan, 2025; Lam, 2023). 5E teaching model has large differences than traditional lecture-based teaching approaches, and it belongs to the inquiry-based pedagogical framework. Furthermore, 5E teaching model also emphasizes the alignment between teaching behaviors of teachers and learning behaviors of students (Grau, 2021). In 5E teaching model, students are positioned as the primary learning agents, while teachers play the important roles of facilitators and guides. According to literatures reported, 5E teaching model has distinct advantages in students' development processes, which can effectively promote the cultivation of learning abilities and stimulation of innovative thinking, as illustrated in Figure 1.

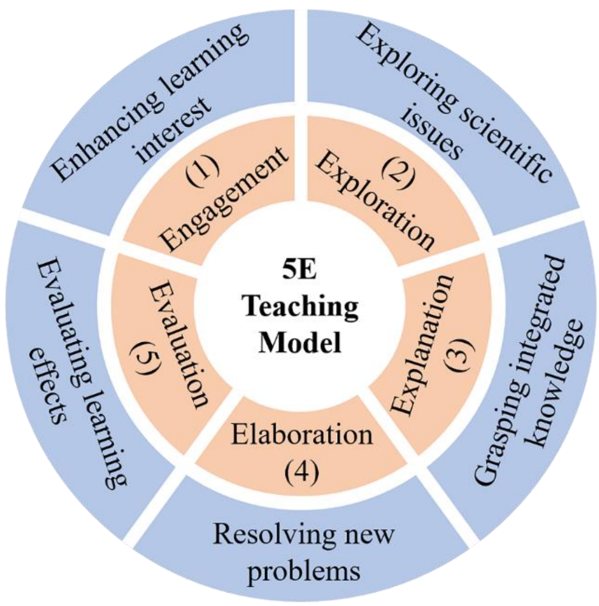

Figure 1. 5E teaching model and its advantages.

Engagement Phase

Interest is the greatest motivation for learning. During engagement phase, teachers should establish a preliminary understanding of students' acquired knowledge and experiences, then carefully designing the content-related teaching cases and contextual problems from real-living. Alternatively, teachers adopt some engaging teaching tools or multimedia materials for attracting students' concentrations and participations. Subsequently, teachers can encourage students to express their own understandings and conjectures through the heuristic questionings, thereby stimulating their curiosities and desires for knowledge and igniting interests in university physics course, further laying a solid foundation for subsequent in-depth learning.

Exploration Phase

In exploration phase, teachers should focus on guiding students to explore questions and cultivate independent inquiry and problem-solving abilities. Teachers can enhance students' practical capacity to address challenges independently by designing open-ended scientific questions in class, which stimulates their critical thinking and exploratory consciousness. For instance, students can improve their experimental skills and data analysis abilities through the careful hands-on operation and systematic data recording in modern physical experiments course. Meanwhile, teachers provide the suitable theoretical guiding for students at experimental process, which can ensure abundant spaces for self-directed exploration. Furthermore, group cooperative learning acts as a key component of physics course, which can further strengthen their teamwork and communication skills by gathering discussion, exchanging ideas and sharing findings. Therefore, students can quickly grasp the principles of physics experiments and acquire abilities to apply the relevant knowledge through above approaches.

Explanation Phase

In explanation phase, the central tasks of teachers guide students to systematically organize and summary knowledge acquired through explorations, further helping them to construct the coherent knowledge framework and deepen physical concepts understanding. Crucially, this process aims to foster an awareness of integrating theory with practice, thereby improving their abilities to apply physics knowledge. During this stage, it's very essential for the interactive communication and heuristic questioning between teacher and students. Teachers can propose some in-depth questions according to students' cognitive levels, further stimulating reflective thinking. Besides, teachers can also lead them to summarize physical principles, thereby developing their generalization and presentation abilities. Class demonstration is also essential in this stage, so teachers not only clarify the meaning of physical concepts but also use vivid examples to help students to build an intuitive perception of physical world. Combination with cutting-edge cases (e.g. quantum communication, superconducting technology, et al.) is a good teaching strategy for students, which can greatly spark their interests in physics knowledge. Afterwards, students are motivated to actively express their ideas by organizing group discussions or advocating debates. Moreover, teacher can also encourage students to involve in research projects or innovative experiments, thereby helping them to cultivate critical thinking, creativity and complex problems-solving ability in practice.

Elaboration Phase

In elaboration phase, teachers guide students to apply the learned contents in different contexts by diverse tasks and projects, which greatly facilitate the transfer and reinforcement of physics knowledge, thereby fostering their comprehensive and flexible subject application skills. Especially, teachers can design some challenging problems, which require students to use prior knowledge solving real-life problems in new situations. This process deepens their understanding of knowledge essence and strengthens ability to connect theory with practice, allowing them to realize the universality and adaptability of physics knowledge. Furthermore, teachers should advocate interdisciplinary thinking by integrating physics concepts with other fields (such as mathematics and engineering), thereby broadening students' intellectual visions and enhancing capacities of solving cross-disciplinary problems. In addition, authentic scenarios construction is crucial in this phase. Teachers can organize projects-based learning or innovation practices, guiding students to explore the underlying mechanisms of physical phenomena and promote the transformation of theoretical knowledge into practice. For example, students develop 3D visual projection applications based on the principle of light polarization, or design temperature and humidity sensors utilizing the variation of optical-fiber refractive index with environmental conditions. Through participation in authentic projects and research activities, students can acquire practical understandings of physical knowledge application, thereby cultivating their innovative consciousness and practical skills.

Evaluation Phase

Evaluation phase as the final component of 5E teaching model serves a core function of examining students' learning processes and outcomes, further providing feedback and recognition for teacher. This phase emphasizes the formative assessment, which is integrated throughout the entire instructional process. Evaluation phase includes several key parts of implementation strategies. Firstly, the diversified evaluation indexes should contain teacher assessment, student self-assessment and peer evaluation parts. Different with traditional class testing and lab reports, teachers should employ project presentations, open-ended questions and cases analysis to comprehensively evaluate students' deep understanding of physics knowledge and practical abilities of problem-solving in real-life. Secondly, the evaluation contents should go beyond the conventional knowledge points and focus on students' feedback on classroom performance, problem-solving abilities, communication and collaboration abilities in group work. Finally, the introduction of self-evaluation and peer-evaluation mechanisms can promote students to systematically reflect on their learning outcomes and processes. These strategies not only foster their capacities of autonomous learning and collaborative skills but also help them to timely adjust unsuitable learning behaviors. Furthermore, teachers can make appropriate adjustments to their teaching methods based on the feedback from comprehensive evaluations, achieving the fundamental goals of enhancing instructional effectiveness and promoting student development.

The Feasibility of 5E Teaching Model

As everyone known, 5E teaching model usually contains Engagement, Exploration, Explanation, Elaboration and Evaluation phases (Lam, 2023; Joswick, 2024). Meanwhile, the essence of 5E teaching model belongs to the constructivist philosophy, and it also emphasizes a student-centered approach (Sari, 2017). Thus, it's feasible to the implement 5E teaching model in the class of university physics education, as presented in Figure 2.

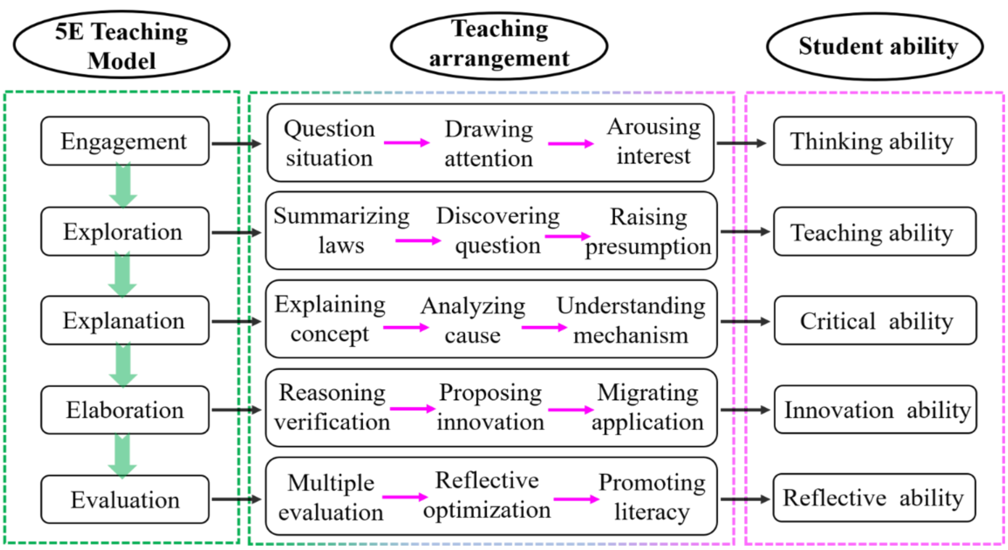

Figure 2. Teaching process of university physics education based on 5E teaching model.

Feasibility of Theoretical Alignment and Educational Philosophy

(1) Alignment with university educational objectives: 5E teaching model attaches importance to cultivate scientific inquiry skills, critical thinking and problem-solving abilities, which are consistent with the overarching goals of higher education to foster innovative and research-oriented talents.

(2) Deepening constructivist learning theory: Students have obtained a certain foundational physics knowledge. 5E teaching model can lead them to construct knowledge upon their existing cognitive frameworks, rather than the passive reception. Therefore, this model is more aligned with the principles of advanced learning.

(3) Addressing the shortcomings of traditional lecture-based method: The traditional "cramming" method of instruction often leads to passive learning and difficulties in understanding abstract physical concepts. However, 5E teaching model effectively facilitates the fundamental concept understanding by Exploration and Explanation phases. University physics education needs more than the transmission of knowledge, and it's fundamentally concerned with the cultivations of scientific literacy and mindset. Crucially, the core of 5E teaching model advocates students to think and practice like scientists. For instance, "electromagnetic induction" content of university physics is instead of directly presenting Faraday's Law, while this class begins with a question of "How can we make a bulb light up without connecting it to a power source?" (Engagement). Subsequently, students carefully proceed to connect coils and magnets to experiment (Exploration), then summarizing the rules from observed phenomena (Explanation). Physics contents are further exhibited by applying the corresponding knowledge to real-life problems like generators and transformers (Elaboration), while the formative assessment is also throughout the whole learning process (Evaluation). This approach perfectly accords with the demands of university education for deep learning and competency improvement.

Feasibility in Curriculum Design and Teaching Practice

(1) Modular and thematic implementation: It's unnecessary for a complete overhaul of the existing curriculum. Instead, pilot implementations can be conducted by applying 5E instructional design to the core concepts or key chapters (like simple harmonic motion and optical interference). Therefore, a gradual and modular strategy is the most viable approach.

(2) Deep integration with laboratory instruction: University physical experiments are naturally consistent with "Exploration" phase. Therefore, 5E teaching model can supply an overarching framework for experimental course, and transform traditional verification experiments to inquiry-based researches, thereby enhancing the pedagogical value of practical sessions.

(3) Development and integration of teaching resources: Pre-class (Engagement/Exploration): Use online videos or simulation software (like PhET and Comsol), and pose cutting-edge physics questions or everyday phenomena to spark students' interests and curiosities. In-class (Explanation/Elaboration): Adopt a flipped classroom approach, class time is used to group discussions, teacher explanations and practical applications. Post-class (Elaboration/Evaluation): Open-ended projects, short research papers or more challenging problems can be assigned to extend learning and evaluate understanding. Practical feasibility is paramount in university physics education. For instance, "momentum conservation" content can begin through a video of colliding billiard balls or a rocket launch (Engagement). Then students can collect the corresponding data through collision experiments using an air track (Exploration), further guiding them to analyze data and derive momentum conservation Law (Explanation). Subsequently, students utilize the obtained knowledge to explain the principles of spacecraft attitude adjustment (Elaborate). Finally, this part physics knowledge can be evaluated through designing

fundamental experiments or complex calculation problems (Evaluation). Therefore, 5E teaching model effectively repackages the traditional content, infusing it with the vitality of scientific inquiry.

Feasibility Concerning Student Adaptation and Learning Outcomes

(1) Stimulating intrinsic learning motivation: “Engagement” and “Exploration” phases effectively stimulate students’ curiosities and learning desires, thereby shifting a passive state of “required to learn” to an active state of “wanted to learn”.

(2) Promoting deep learning and conceptual change: Knowledge constructed through students’ exploration is more profoundly understood and persistently memorized, further facilitating the correction of pre-existing scientific misconceptions.

(3) Cultivating comprehensive skills: 5E teaching model is benefitted to systematically develop students’ abilities of teamwork, communication, data analysis and scientific inquiry.

University students represent the suitable people for carrying out 5E teaching model due to the strong autonomous learning and logical thinking capacities, which can guide them to address some common issues of “understanding content but being unable to solve problems”. 5E instructional strategy gradually leads students to undergo knowledge generation processes and understand physical principle underlying formulas, so they can quickly tackle novel problems by drawing upon logical deduction rather than relying on memorized formulas. Lastly, these successful learning experiences can reinforce their learning motivation, thereby establishing a virtuous cycle.

The Applications and Values of 5E Teaching Model

5E teaching model fundamentally transforms the traditional physics classroom from teacher-led to student-centered, further providing a systematic framework for reforming university physics education. Its core applications and values are manifested in three primary aspects.

Firstly, it subverts the “cramming” method of teaching, and guides students from intriguing physical phenomena to construct knowledge through hands-on exploration and data analysis. This model enables a profound understanding for physical essence underlying abstract laws (like electromagnetic induction), and effectively corrects prescientific misconceptions for students.

Secondly, this model transforms classroom into a microsite of scientific research, which promotes students to experience the completely scientific process of “posing questions, experimental inquiries, explaining conclusions and migrating applications”. This approach effectively cultivates their scientific inquiry skills, teamwork abilities and critical thinking.

Finally, this model directly addresses students’ common dilemmas of “understanding lectures but being unable to solve practical problems”. By explaining the physical principles underlying formulas, it enables students to form the deep comprehension, thereby drawing upon research experiences for physical reasoning rather than relying memorized formulas.

Obviously, the prominent values of 5E teaching model are successfully shifted learning method from passive reception to active investigation, further stimulating students’ intrinsic motivation of deep learning and conceptual change. It’s not only an innovation in teaching methodology but also a reconstruction of educational paradigm, thereby cultivating well-rounded talents with solid knowledge, exceptional scientific literacy and innovative capabilities. Therefore, 5E teaching model has profound significances and values for improving the quality of university physics education.

Conclusion

In summary, this research primarily analyzes and discusses the significant applications and values of 5E teaching model in university physics education. 5E teaching model proposes a "active learning idea of student-centered" by Engagement, Exploration, Explanation, Elaboration and Evaluation phases. It effectively attracts students' learning interests by creating authentic problem scenarios, then guides them in autonomous inquiry through experiments or simulations. Teachers assist them to accomplish the construction of physical concepts, further applying physics knowledge to solve complex problems. Importantly, the prominent values of 5E teaching model are successfully shifted learning method from passive reception to active investigation, thereby overcoming the drawbacks of the traditional "cramming" pedagogy, and stimulating students' intrinsic motivation of deep learning and conceptual change. Teaching practice demonstrates that 5E teaching model not only enhances students' deep understanding of physical knowledge but also contributes to the development of scientific literacy and innovative spirit, further providing strong supports for cultivating innovative talents in the new era.

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