Creative Education, 2025, 16(3), 417-427
https://www.scirp.org/journal/ce
ISSN Online: 2151-4771
ISSN Print: 2151-4755

Research on Effective Articulation between Secondary and College Physics Education under Emerging Engineering Education: A Case Study of Particle Motion Description

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How to cite this paper: Wang, X. L., & Gao, H. Y. (2025). Research on Effective Articulation between Secondary and College Physics Education under Emerging Engineering Education: A Case Study of Particle Motion Description. *Creative Education, 16,* 417-427.
https://doi.org/10.4236/ce.2025.163026

Received: February 23, 2025
Accepted: March 22, 2025
Published: March 25, 2025

Abstract

This study explores the effective articulation between secondary and college physics education through the lens of particle motion description. By analyzing current challenges in curricular continuity and aligning with the demand for cultivating innovative engineering talents under the Emerging Engineering Education framework, we propose concrete strategies including hierarchical cognitive construction strategies, deep integration of mathematics and physics, progressive cultivation of modeling thinking, and smart technology-empowered instruction. The results demonstrate that these approaches can systematically enhance pedagogical coherence between secondary and college physics education.

Keywords

College Physics, Secondary Physics, Curricular Articulation, Particle Motion, Instructional Strategies

1. Introduction

Physics, as a fundamental discipline in natural sciences, plays a crucial role in cultivating students' scientific literacy, scientific thinking methods, and research capabilities. With the advancement of "Emerging Engineering Education", higher demands are placed on the cultivation of innovative engineering and technological talents, emphasizing the development of practical skills, innovative abilities,

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and international competitiveness. College physics, as a vital foundational course for science and engineering students, is irreplaceable in fostering scientific thinking and problem-solving skills (Jiang et al., 2024; Sun & Long, 2018; Holcomb, Resnick, & Rigden, 1987; Zheng et al., 2011).

Numerous studies both domestically and internationally indicate that there are prevalent difficulties in the articulation between secondary and college physics education (Xu, 2014; Liu, 2011; Wang et al., 2023). Teaching practices reveal that current articulation issues primarily manifest in differences in teaching objectives, methods, students' learning habits and abilities, and the integration with engineering applications. Particle motion is one of the most fundamental and important concepts in physics, permeating the entire physics system. By studying the articulation issues in the description of particle motion in secondary and college physics education, we can not only provide guidance for improving specific teaching content but also offer insights for the articulation of the entire physics education system.

To explore effective articulation under the Emerging Engineering Education framework, this research adopts a multi-method approach, including literature review, teaching practice design, implementation and analysis, comparative assessment, and feedback-driven strategy refinement. We first diagnose differences in objectives, methods, and engineering application integration through an analysis of existing literature. Next, we design and implement teaching practices incorporating strategies such as hierarchical cognitive construction, deep integration of mathematics and physics, progressive modeling thinking, and smart technology empowerment. Finally, we propose recommendations to enhance physics education articulation within the Emerging Engineering Education context.

2. Analysis of Articulation Issues in Secondary and College Physics Education

2.1. Differences in Teaching Objectives

Secondary physics education primarily focuses on imparting basic knowledge and developing test-taking skills, emphasizing intuitive descriptions of physical phenomena and simple calculations. For example, in the description of particle motion, secondary education mainly covers uniform linear motion and uniformly accelerated linear motion, using elementary mathematical tools for simple calculations. This teaching objective aligns with the cognitive level of secondary students and the requirements of college entrance examinations but also leads to a superficial understanding of physical concepts, lacking in-depth exploration of the underlying principles. For instance, students may proficiently calculate speed and displacement in uniformly accelerated motion but have a vague understanding of the vector nature and instantaneous characteristics of velocity and acceleration.

In contrast, college physics education not only requires students to master the basic theories and experimental skills of physics but also emphasizes the cultivation of comprehensive abilities, including the ability to establish physical models, perform qualitative analysis, estimation, and quantitative calculations. Taking particle motion as an example, college education demands mastery of more complex scenarios such as curvilinear motion and relative motion, employing advanced mathematical tools like vector analysis and calculus for precise descriptions. For instance, velocity is defined as the first derivative of the position vector with respect to time, and acceleration as the first derivative of velocity or the second derivative of the position vector with respect to time. This leap in difficulty makes it challenging for many students to adapt to the requirements of college physics, affecting their learning outcomes and interest.

2.2. Differences in Teaching Methods

Secondary physics education has relatively less content and more class hours, with a slower teaching pace. Teachers often adopt a didactic approach, combining lectures with practice, focusing on skill training. For example, when teaching uniformly accelerated linear motion, teachers use numerous examples and exercises to help students master relevant formulas and calculation methods. While this approach helps students grasp basic knowledge in the short term, it is not conducive to developing independent learning and innovative thinking.

In contrast, college physics education has extensive content and fewer class hours, with a fast-paced teaching schedule and a large amount of information delivered in class. College education emphasizes the cultivation of students' independent learning and inquiry-based learning abilities, focusing on the enhancement of logical and critical thinking. For instance, when teaching curvilinear motion of particles, teachers typically guide students to independently derive motion equations and related physical quantities by establishing coordinate systems and analyzing vector changes. This teaching method requires students to have strong independent learning and logical thinking abilities, but many students struggle to adapt to the pace of college physics due to a lack of these skills upon entering college.

2.3. Differences in Students' Learning Habits and Abilities

In secondary school, students are more dependent on teachers, with weak independent learning awareness. Teachers usually provide detailed guidance and abundant exercises, and students are accustomed to following the teacher's arrangements. For example, when learning physical formulas, students often memorize and apply them through repetitive practice, with less initiative to explore the derivation and physical meaning of the formulas.

Upon entering college, the learning mode shifts from teacher-centered to student-centered, emphasizing the cultivation of independent learning abilities. College physics courses require students to think independently, learn autonomously, and possess strong problem-solving skills. For instance, when dealing with complex particle motion problems, students need to independently establish physical models and use mathematical tools for analysis and solution. However, many students, due to a lack of independent learning abilities and innovative thinking, find it difficult to adapt to this shift, leading to poor learning outcomes.

2.4. Requirements for Application-Oriented Undergraduate Institutions under Emerging Engineering Education

Under the framework of "Emerging Engineering Education", newly established application-oriented undergraduate institutions place greater emphasis on cultivating students' practical and application abilities. College physics courses not only need to provide students with a solid theoretical foundation but also closely integrate with engineering practice to develop students' engineering thinking and problem-solving skills. However, there is a significant gap in the articulation between secondary and college physics education regarding engineering applications. For example, in secondary school, students have limited exposure to the application of physical knowledge in engineering and lack a perceptual understanding of real engineering problems. Upon entering college, students often struggle to connect the physics knowledge they have learned with actual problems when faced with complex engineering physics issues, affecting the development of their engineering practice abilities.

Taking particle motion as an example, secondary students primarily describe object motion through simple motion equations and formulas, whereas in college, students need to master more complex forms of motion, such as curvilinear and relative motion, and apply them to real engineering problems. For instance, in aerospace engineering, relative and curvilinear motion of particles are common issues, requiring students to use tools like vector analysis and calculus to solve them. However, due to the lack of systematic learning of these complex motion forms in secondary school, students often find it difficult to quickly adapt to this transition upon entering college, affecting their understanding and problem-solving abilities in engineering contexts.

3. Necessity of Articulation between Secondary and College Physics Education under Emerging Engineering Education

The core goal of "Emerging Engineering Education" is to cultivate innovative engineering and technological talents that meet national strategic needs, emphasizing the development of engineering practice abilities, innovative capabilities, and international competitiveness. College physics, as a crucial foundational course for science and engineering students, plays an irreplaceable role in fostering scientific thinking and practical problem-solving skills. However, the current disconnect between secondary and college physics education severely impacts students' deep understanding and application of physical knowledge in college, thereby constraining the achievement of talent cultivation goals under the "Emerging Engineering Education" framework. Therefore, achieving effective articulation between secondary and college physics education is not only necessary for improving the quality of physics education but also an inevitable requirement for talent cultivation under the "Emerging Engineering Education" context.

3.1. Key Role of College Physics in Emerging Engineering Education

College physics courses are not only essential for students to master basic physical knowledge but also key to cultivating scientific thinking, innovative abilities, and practical problem-solving skills. Under the "Emerging Engineering Education" framework, college physics courses need to be closely integrated with engineering practice, providing students with a solid theoretical foundation and practical skills. For example, in majors such as aerospace, mechanical engineering, and electronic information, the description of particle motion is not only part of the basic theory but also crucial for solving real engineering problems. Students need to master complex motion forms like curvilinear and relative motion and use advanced mathematical tools such as vector analysis and calculus for precise description and calculation. The cultivation of this ability requires gradual guidance starting from secondary school, helping students progressively build a deep understanding of physical concepts through step-by-step teaching methods.

3.2. Importance of Articulation between Secondary and College Physics Education for Talent Cultivation in Emerging Engineering Education

Currently, secondary physics education primarily focuses on imparting basic knowledge and developing test-taking skills, emphasizing intuitive descriptions of physical phenomena and simple calculations. For instance, in the description of particle motion, secondary education mainly covers uniform linear motion and uniformly accelerated linear motion, using elementary mathematical tools for simple calculations. This teaching objective aligns with the cognitive level of secondary students and the requirements of college entrance examinations but also leads to a superficial understanding of physical concepts, lacking in-depth exploration of the underlying principles.

In contrast, college physics education not only requires students to master the basic theories and experimental skills of physics but also emphasizes the cultivation of comprehensive abilities, including the ability to establish physical models, perform qualitative analysis, estimation, and quantitative calculations. Taking particle motion as an example, college education demands mastery of more complex scenarios such as curvilinear motion and relative motion, employing advanced mathematical tools like vector analysis and calculus for precise descriptions. For instance, velocity is defined as the first derivative of the position vector with respect to time, and acceleration as the first derivative of velocity or the second derivative of the position vector with respect to time. This leap in difficulty makes it challenging for many students to adapt to the requirements of college physics, affecting their learning outcomes and interest.

Under the "Emerging Engineering Education" framework, this disconnect not only affects students' deep understanding of physical knowledge but also constrains the development of their engineering practice abilities. Newly established application-oriented undergraduate institutions place greater emphasis on students' practical and application abilities, requiring college physics courses to be closely integrated with engineering practice to cultivate engineering thinking and problem-solving skills. However, there is a significant gap in the articulation between secondary and college physics education regarding engineering applications. For example, in secondary school, students have limited exposure to the application of physical knowledge in engineering and lack a perceptual understanding of real engineering problems. Upon entering college, students often struggle to connect the physics knowledge they have learned with actual problems when faced with complex engineering physics issues, affecting the development of their engineering practice abilities.

3.3. Promoting Role of Articulation between Secondary and College Physics Education in Emerging Engineering Education

Achieving effective articulation between secondary and college physics education can lay a solid foundation for cultivating high-quality composite talents with a strong physical foundation, innovative abilities, and practical skills under the "Emerging Engineering Education" framework. Through step-by-step teaching methods, strengthening the application of mathematical tools, emphasizing the cultivation of physical thinking, and innovating teaching methods, students can better adapt to the requirements of college physics, improving their learning outcomes and interest. For example, in the teaching of particle motion, starting from the familiar uniform linear motion in secondary school, gradually introducing more complex scenarios such as curvilinear and relative motion. Additionally, when introducing new mathematical tools, attention should be paid to connecting with existing knowledge to help students establish links between new and old knowledge.

Furthermore, through innovative teaching methods such as computer simulations and virtual experiments, various scenarios of particle motion can be visually demonstrated, helping students understand complex motion forms. For instance, computer simulations can visually display the trajectory and velocity changes in projectile motion, aiding students in understanding complex motion situations. Additionally, designing interesting physical problems or experiments can stimulate students' interest in learning and desire for exploration.

In summary, achieving effective articulation between secondary and college physics education can not only improve the quality of physics education but also provide strong support for cultivating high-quality composite talents with a solid physical foundation, innovative abilities, and practical skills under the "Emerging Engineering Education" framework. Therefore, exploring effective articulation between secondary and college physics education has significant theoretical and practical value.

4. Implementation Strategies for Articulation between Secondary and College Physics Education

In secondary school, the focus is on uniform and uniformly accelerated linear motion, establishing a scalar description system for displacement, average velocity, etc., through algebraic operations, laying a preliminary foundation for kinematics. However, limited by mathematical tools, complex motions (such as three-dimensional curvilinear motion and non-inertial system analysis) are difficult to analysis. In college, it is necessary to build a systematic vector calculus framework, with velocity and acceleration strictly defined as calculus expressions. This methodological leap from scalar superposition to vector differentiation and from special solutions to universal integration poses multiple challenges for students. To address the typical problems in articulation and align with the talent cultivation requirements under the "Emerging Engineering Education" framework, the following strategies are proposed based on teaching practices:

4.1. Hierarchical Cognitive Construction Strategy

As shown in Table 1: based on students' cognitive development patterns, a three-level progression path is constructed: starting from one-dimensional uniform linear motion, transitioning through two-dimensional projectile motion, and finally expanding to three-dimensional curvilinear and relative motion analysis. Using high-speed rail acceleration as a cognitive anchor, visualizing projectile trajectories to establish the concept of two-dimensional vectors, then connecting to the vector nature of normal acceleration through circular motion cases, and ultimately achieving three-dimensional reference frame transformation in the scenario of raindrop relative motion in a moving train. Key links involve setting cognitive conflict tasks, such as contemplative activities on "observing raindrop trajectories inside a moving train," guiding students to verify hypotheses through

Table 1. Hierarchical cognitive construction strategy.

Articulation Dimension	Secondary School Content/Method	College Deepening Content/Method	Cognitive Development Strategy	Teaching Methods and Tools	Engineering Application and Skill Cultivation
Motion Form	Uniform linear motion (one-dimensional scalar analysis)	Curvilinear and relative motion (three-dimensional vector analysis)	Step-by-step case chain: High-speed rail linear acceleration → projectile motion → circular motion → raindrop relative motion	Case comparison method + simulation	Links motion trajectory analysis to engineering problems (e.g., transportation, track design), fostering modeling and data analysis skills
Mathematical Tools	Algebraic operations (e.g., $v = \Delta x/\Delta t$)	Vector calculus (e.g., $v = dr/dt$, $a = dv/dt$)	Variable acceleration problem chain: Uniform acceleration → linear resistance → nonlinear resistance	Just-in-time teaching + symbolic computation demonstration	Develops skills in using mathematical tools for engineering dynamics (e.g., vehicle acceleration calculations)
Model Construction	Particle model under a single reference frame	Motion decomposition and synthesis under multiple reference frames	Reference frame debate: "Is the trajectory of raindrops in a moving train straight or curved?"	Peer instruction + multi-reference frame simulation demonstration	Equips students to construct multi-reference frame models for engineering applications (e.g., aircraft sensor data fusion)

multi-reference frame simulations, completing the cognitive leap from scalar superposition to vector synthesis.

4.2. Deep Integration Strategy of Mathematics and Physics

As shown in Table 2: establishing a bidirectional mapping mechanism between mathematical tools and physical concepts, at the motion description level, capturing free-fall processes with high-speed cameras, comparing numerical differentiation with analytical solutions to intuitively reveal the differential nature of instantaneous velocity; at the equation-solving level, designing problem chains with gradually changing air resistance coefficients, guiding students to independently program Euler's method for numerical integration, understanding the universality of differential equations. Special emphasis is placed on the three-dimensional extension of vector operations, using drone trajectory planning cases to analyze the spatial synthesis rules of velocity vectors with three-dimensional modeling.

Table 2. Deep integration strategy of mathematics and physics.

Articulation Dimension	Secondary School Content/Method	College Deepening Content/Method	Cognitive Development Strategy	Teaching Methods and Tools	Engineering Application and Skill Cultivation
Instantaneous Quantity Description	Preliminary limit concept ($v = \lim_{\Delta t \to 0}\Delta x/\Delta t$)	Strict differential definition ($v = dr/dt$)	Experimental verification: Analyze free-fall video, compare numerical differentiation with analytical differentiation results	High-speed camera + numerical simulation demonstration	Enhances real-time measurement and data processing skills for engineering testing via data analysis training
Motion Equation Solving	Special algebraic solutions (e.g., $x = 1/2at^2$)	Universal integration method ($x = \int v dt$, $v = \int a dt$)	Problem comparison: Limitations of algebraic solutions vs. universality of integration for air resistance falling problems	Computational thinking training + numerical simulation demonstration	Builds numerical computation skills for complex engineering problems (e.g., drone path planning)
Vector Operations	Two-dimensional orthogonal decomposition (v_x, v_y)	Three-dimensional vector synthesis ($\mathbf{v} = v_x\mathbf{i} + v_y\mathbf{j} + v_z\mathbf{k}$)	Engineering case: Vector description and optimization of drone three-dimensional trajectories	Mathematical modeling + vector synthesis animation	Connects to aviation, aerospace, and robotics, enhancing vector modeling for practical engineering solutions

4.3. Progressive Cultivation Strategy of Modeling Thinking

As shown in Table 3: implementing a multi-scale modeling ability training program, first, consolidating the abstraction principles of particle models by quantitatively comparing the size of high-speed rail carriages with running distances to establish idealization conditions; then introducing the concept of rigid bodies to analyze the decomposition of wheel translation and rotation; finally expanding to continuous medium descriptions, using numerical simulations to demonstrate fluid element motion. Simultaneously, critical thinking training is conducted, organizing whiteboard derivation competitions to argue for the centripetal acceleration formula, thoroughly deconstructing the misconception that "uniform speed implies no acceleration" through differential derivation of $a_n = v^2/r$.

Table 3. Progressive cultivation strategy of modeling thinking.

Articulation Dimension	Secondary School Content/Method	College Deepening Content/Method	Cognitive Development Strategy	Teaching Methods and Tools	Engineering Application and Skill Cultivation
Model Abstraction Ability	Simple particle model (ignoring shape and size)	Multi-scale modeling (particle → rigid body → continuous medium)	Problem chain design: "When can a high-speed rail carriage be considered a particle? How to decompose wheel motion?"	Multi-body simulation demonstration + peer instruction	Develops simplification and abstraction skills for engineering design (e.g., structural mechanics)
Spatial Thinking Ability	Two-dimensional motion diagramming	Three-dimensional vector field analysis (velocity field, acceleration field)	Virtual experiment: Dynamically demonstrate the relationship between curvature and acceleration vectors in projectile motion	Augmented reality interaction + three-dimensional trajectory plotting	Enhances spatial understanding for engineering drawing, 3D modeling, and simulation
Critical Thinking	Distinguish misconceptions (e.g., "acceleration direction is the same as velocity")	Argue complex propositions (e.g., "the nature of acceleration in uniform circular motion")	Academic seminar: Strictly derive $a_n = v^2/r$ through differentiation, critique the misconception that "uniform speed = no acceleration"	Peer instruction + whiteboard derivation competition	Strengthens critical thinking and rigorous analysis for engineering project evaluation

4.4. Smart Technology-Empowered Teaching Strategy

As shown in Table 4: this strategy harnesses modern information technology to create a hybrid learning environment blending virtual and real elements, enhancing comprehension of complex physics concepts and engineering practice skills. Building a hybrid learning ecosystem that integrates virtual and real elements, before class, triggering motion trajectory preview modules through AR markers; during class, using simulation platforms for real-time diagnosis of typical errors such as vector direction confusion (e.g., $\Delta r \neq \Delta r$); after class, assigning parameter sensitivity analysis tasks, requiring students to adjust resistance coefficients in virtual labs to observe trajectory evolution. Establishing a learning behavior database, using machine learning algorithms to identify error patterns, and achieving personalized error-prone question to assign. Finally, through collaborative whiteboards, completing three-dimensional motion decomposition defenses, forming a teaching closed loop of "embodied experience, data diagnosis, and precise remediation". This approach enhances teaching intuitiveness and interactivity through visualization, significantly improving students' learning experiences and engineering competencies.

Table 4. Smart technology-empowered teaching strategy.

Articulation Dimension	Secondary School Content/Method	College Deepening Content/Method	Cognitive Development Strategy	Teaching Methods and Tools	Engineering Application and Skill Cultivation
Virtual Simulation	Animation demonstration of two-dimensional motion	Interactive programs for parameterized three-dimensional motion	Develop independent exploration tools: Adjust air resistance coefficients, observe trajectory changes in real time	Virtual lab + parameter sensitivity analysis	Simulates engineering parameter optimization (e.g., wind tunnel fluid analysis), enhancing design/experimental skills
Intelligent Diagnosis	Manual grading of paper assignments	AI algorithms analyze problem-solving processes (e.g., detect vector direction errors)	Deploy machine learning models: Identify common error patterns in student assignments	Intelligent assessment + personalized error-prone question to assign	Develops skills in data mining and smart diagnostics for engineering quality control
Hybrid Teaching	Traditional classroom lecturing	Just-in-time teaching collaborative mode (pre-class testing - in-class discussion - post-class expansion)	Build a learning closed loop: Online preview → in-class testing → group programming tasks → virtual defense	Augmented reality markers + just-in-time teaching	Fosters cross-platform collaboration and project management skills in engineering practice

5. Conclusion

Taking the description of particle motion as an example, this study deeply explores the current status, problems, and improvement strategies for the articulation between secondary and college physics education. The research finds that there are significant differences in content depth, teaching methods, and student ability cultivation between secondary and college physics education. These differences lead to substantial learning challenges for students upon entering college, affecting their deep understanding of physical knowledge and the improvement of application abilities. To address these issues, strategies such as hierarchical cognitive construction, deep integration of mathematics and physics, progressive cultivation of modeling thinking, and smart technology-empowered teaching are proposed. Teaching practices have verified that these strategies can effectively promote the articulation between secondary and college physics education, helping students better adapt to the requirements of college physics and improving their learning outcomes and interest. Under the "Emerging Engineering Education" framework, these articulation strategies not only provide specific guidance for teaching the description of particle motion but also offer valuable insights for the articulation of the entire secondary and college physics education system. By achieving effective articulation between secondary and college physics education, a solid foundation can be laid for cultivating high-quality composite talents with a strong physical foundation, innovative abilities, and practical skills under the "Emerging Engineering Education" framework.

Funding

This project was supported by the "Teaching Content and Curriculum System Reform Project of Guizhou Provincial Higher Education (No. 2021294, No. 2021297)" and the "Guizhou University of Engineering Science Improvement Project".

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Holcomb, D. F., Resnick, R., & Rigden, J. S. (1987). New Approaches to Introductory Physics. *Physics Today, 40,* 87-87. https://doi.org/10.1063/1.2820029

Jiang, C. W., Fang, A. P., Zhang, E. H. et al. (2024). Exploration and Practice of College Physics Teaching Reform under the Traction of Emerging Engineering Education. *College Physics, 43,* 59-66.

Liu, R. (2011). Analysis of Role Transition from Secondary to College for University Students. *Going Abroad and Employment, No.14,* 11.

Sun, G. H., & Long, Y. Z. (2018). Discussion on the Teaching Research of Articulation Issues between College and Secondary Physics. *Physics and Engineering, 28,* 59-62.

Wang, X. O., Zhang, L. L., Yuan, C. X. et al. (2023). Research and Practice on the Articulation of Physics Teaching between Secondary and College under the "3 + 3" New College Entrance Examination System. *Physics and Engineering, 33,* 162-166. https://doi.org/10.26599/PHYS.2023.9320127

Xu, H. X. (2014). Effective Articulation of Mechanics Teaching in College and Secondary Physics. *Physics and Engineering, No. z2,* 83-85.

Zheng, H. W., Kang, M., Ren, F. Z. et al. (2011). Research on the Articulation of Modern Physics Sections in College and Secondary Physics Courses. *Physics and Engineering, 21,* 45-48.