Generalization of Course Construction of Engineering Physics to Virtual Teaching-Research and Deep Science Popularization

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Abstract. Enhancing the scientific and technological literacy of Chinese citizens is the fundamental approach to realizing the innovation-driven strategy, as reflected in *Xi Jinping*'s "Two Wings Theory." Engineering physics courses at local universities have a responsibility, advantage, and opportunity to undertake this crucial task. Using information technology and "intelligence +" as tools to collaborate on physics curriculum development and popular science, this approach integrates fundamental engineering physics courses with specialized university programs to strengthen students' understanding of physical principles and enhance the practical application of theory in engineering. The study identifies the core and four characteristics of in-depth popular science as the foundation and far-reaching dissemination of scientific and technological literacy. It establishes a four-tier platform for engineering physics courses, creates teaching methods that combine online and offline, large and small classes, and theoretical analysis with practical exploration, and constructs three teaching paths for curriculum and ideology. After a decade of engineering education practice, it achieves synergy between physics curriculum development, virtual collaborative research, and in-depth popular science. It has also been awarded the pilot construction of the National Virtual Collaborative Research Office, confirming that virtual collaborative research is both an expansion and generalization direction for engineering physics curriculum development and a means and path for its generalization toward in-depth popular science.

Keywords: Physics curriculum development; In-depth popular science; Virtual collaborative research office; Military background; Curriculum & ideology; Generalization

1. Introduction

In the "Science and Technology Three Meetings" held in 2016, *Xi Jinping* pointed out, "Technological innovation and scientific popularization are the two wings for achieving innovative development [1], and we must place scientific popularization in an equally important position as technological innovation." This perspective is based on a precise and scientific understanding of the development stage of socialism with Chinese characteristics in the new era and represents an important principle for achieving innovative development [2]. In December 2021, the Chinese Academy of Sciences Institute of Science and Technology Strategy, the China Research Institute for Science Popularization, and other units published a research report titled "Profound Understanding of the Significant Meaning of *Xi Jinping*'s 'Two Wings Theory' on Technological Innovation and Scientific Popularization and Proposal for Implementing the 'Great Science Popularization Strategy'" in the People's Political Consultative Daily [3-5]. This report formally introduced the concept of *Xi Jinping*'s "Two Wings Theory." In June 2021, the State Council issued the "Outline of the Action Plan for Enhancing the Scientific Literacy of the Whole Nation (2021-2035)," which is guided by General Secretary *Xi Jinping*'s "Two Wings Theory." This outline extensively covers various aspects, including the improvement of scientific education and popularization efforts at the higher education level during the action to enhance the scientific literacy of young people. In line with these developments, the Ministry of Education in 2021 decided to expand the enrollment of science education majors in higher education institutions. At the same time, comprehensive universities with a focus on science and engineering disciplines should play an active role in innovating science education and popularization efforts.

Based on the specificity and abstraction level of scientific education content, it is now clear that scientific education encompasses two aspects of meaning [6-10]. The first aspect involves the imparting of concrete scientific knowledge and scientific methods, referred to as the substance of scientific education. The second aspect involves cultivating an abstract scientific attitude and scientific spirit, which can be understood as the soul of scientific education. However, this theoretical definition has not yet established a technical connection with the critical foundational courses in fostering scientific and technological literacy among university students, namely, engineering physics (theory/experiment) courses.

Over the past two decades, foundational engineering physics courses at local universities have found themselves in a marginalized position [11]. One of the key reasons for this situation is the weak proactive awareness of the course, leading to homogeneity in course content, delivery methods, and contributions, as well as a growing disconnect from the professional fields it serves. This has resulted in a shrinking space for the course to thrive. Another reason is that the construction of engineering physics courses at local universities has not been effectively aligned with scientific education and innovation in popular science, failing to identify breakthroughs for course specialization.

Fortunately, on July 20, 2021, the Higher Education Division of the Ministry of Education decided to initiate the pilot construction of virtual collaborative research offices (the first batch). This initiative aims to explore the standards, construction pathways, operating modes, and other aspects of constructing new grassroots teaching organizations in the "intelligence + " era. It also seeks to forge high-level teaching teams, nurture achievements in teaching research and practice, create a community for teacher development, and foster a culture of quality, all of which contribute to a comprehensive improvement in teaching capabilities. This opportunity has provided a platform for the distinctive development of foundational engineering physics courses at local universities and has bridged the gap between physics curriculum development and popular science activities.

Therefore, based on the multi-dimensional connotations of scientific education, and with virtual collaborative research as the fundamental approach, we leverage information technology to synergize the demands of engineering majors for basic physics courses with the objectives of physics curriculum development and popular science education content. This not only accomplishes the specialization of engineering physics courses but also extends physics curriculum development into virtual collaborative research and in-depth popular science efforts.

2. The Pedagogical Development Logic of Engineering Physics Courses

2.1 The Logic of the Era. China has entered a new era where high-quality development has become the prevailing theme. For foundational physics courses in higher education, they must proactively adapt to and even lead the "Four New Initiatives," reinforcing the role of these courses in moral and intellectual development. This, in turn, facilitates character formation, ignites intellectual growth, and nurtures the spirit. The new context facing foundational physics courses includes not only the deepening and expansion of the New Engineering Education Initiative promoted by the Ministry of Education in May 2020, but also the comprehensive advancement of ideological and political education in higher education institutions as outlined in the "Guidelines for Curriculum Ideological and Political Education in Higher Education Institutions" issued by the Ministry of Education on May 28, 2020. All of these factors collectively serve as the backdrop and source of inspiration for the reform and development of foundational engineering physics courses.

2.2 The Logic of Demand. Taking Xi'an Technological University as an example, it is a local university associated with China's defense industry. Its distinct defense industry background has led to the establishment of an "Integrated with Two Wings" educational model. This model emphasizes the cultivation of defense industry character, places importance on engineering practice, and aims to nurture well-rounded and specialized applied talents. Consequently, as a fundamental foundational physics course that serves as the essential support for talent development, it must provide high-quality education that contributes to the cultivation of the "loyal and enterprising" defense industry character in students, as well as the enhancement of their engineering practical capabilities in the pursuit of "precision workmanship and broad expertise."

2.3 The Logic of Issues. Foundational physics courses, when serving engineering majors, correspond to the graduation requirements, which include "possessing natural science knowledge necessary to solve engineering problems in the professional field and applying it to solve complex engineering problems." However, for a significant period, these courses have faced various challenges, primarily in five aspects.

Issue one. The foundational physics course system and resources are insufficient in supporting the graduation requirements for engineering majors in schools with a defense industry background. Course content and delivery methods often exhibit homogeneity and generalization across different universities. There is a clear disconnect between these courses and the specialized requirements of defense industry-related majors in terms of content and resources. This directly hampers the enthusiasm for teaching and learning. Scarcity of curriculum ideology and humanities literacy resources affects personalized learning and innovative talent development, with limited impact on value orientation.

Issue two. Traditional physics teaching strategies are rigid, uninteresting, and inefficient, resulting in low student engagement. Physics courses may lack inherent interest advantages in teaching. The teaching methods, primarily relying on "lecture hall + chalkboard + chalk," lack teacher-student interaction. The assessment methods and inadequate use of information technology reduce the intrinsic motivation and cognitive training of students in defense industry-related majors, impacting the effectiveness of character formation and intellectual development.

Issue three. A single assessment method cannot enhance students' enthusiasm for learning physics. In the transition from mass higher education to universalization, students in local universities, compared to prestigious institutions, tend to exhibit lower motivation, especially in courses related to mathematical and logical reasoning, where learning motivation is generally lacking.

Issue four. Amid the fervent development of ideological and political education in courses, substantive and practical teaching issues with fewer refined and precise elements have not been thoroughly resolved. While there is a multitude of ideological and political elements and implementation cases, the work lacks condensation and refinement, affecting practical application.

Issue five. In local universities, despite foundational engineering physics courses being listed as core foundational courses in the curriculum of most majors, they often find themselves on the periphery in terms of active involvement and implementation.

2.4 The Methodological Logic. Considering the talent development needs outlined for Xi'an Technological University, there are three course objectives for foundational engineering physics. In terms of knowledge objectives, the goal is to provide students with a systematic understanding of fundamental concepts, theories, and methods related to various forms of material motion. This helps them form an overall understanding of the framework of the physics discipline and supports the fulfillment of graduation requirements. In terms of skills objectives, the aim is to enhance students' ability to apply physics principles to engineering and develop their capability to connect knowledge. This foundational role facilitates subsequent coursework in defense industry-related majors and supports the fulfillment of graduation requirements. Regarding quality objectives, the goal is to gradually enhance students' physical literacy, enabling them to "speak rationally about objects and create based on principles." This contributes to emotional values centered on the defense industry spirit and aids in character formation and intellectual development.

In light of the aforementioned course objectives, this paper adopts a method that integrates physics curriculum construction with effective popular science, pursuing a path of collaborative innovation. In the development of foundational physics courses, we not only closely align with the specific needs of the served majors and leverage the strengths of our university's academic disciplines but also employ a fusion strategy, taking proactive measures. Furthermore, we synchronize physics curriculum development with in-depth popular science efforts, aiming to explore a new path that bridges foundational physics course construction and in-depth popular science practices.

3. Generalisation of Curriculum Construction to Virtual Teaching and Research

In July 2021, the Ministry of Education formally launched the pilot construction of virtual teaching and research office, because it is a new thing that has never been seen before, so it has become an opportunity for local "doubly non-permanent" colleges and universities to "overtake" in terms of curriculum construction and teaching and research. Xi'an University of Technology (XUT), based on its many years of achievements in engineering physics curriculum construction and curriculum innovation ideas, seized this opportunity, and the university-led "Midwest Basic Physics Cloud Reform Virtual Teaching and Research Office" was awarded the first batch of virtual teaching and research office pilot projects, which realised the generalization of the curriculum construction to the virtual teaching and research, and discovered a new growth point for engineering physics curriculum construction.

Thus, being able to be one of the few virtual teaching and research units in physics for the first time confirms that virtual teaching and research is a means and a path for generalising physics curriculum development towards the deep science popularization.

4. Generalisation of Physics Curriculum to Deep Popular Science in Physics

We have proposed and explained the concept of deep popularisation of science and explored the synergistic relationship between deep popularisation of science and higher education, but we have not refined the characteristic requirements and internal logic of deep popularisation of science, which restricts further exploration of the implementation modes, paths and strategies of deep popularisation of science. If the construction of engineering physics curriculum is synergised with popular science, it will be easy to achieve the promotion and generalisation of the former to the latter.

Four Types of Characteristics of In-Depth Popularisation of Science. We believe that popularisation of science is a lifelong scientific education and interactive process for all people with the aim of improving citizens' scientific quality and achieving the harmonious development of individuals, society and nature. Compared with the shallow generalisation of scientific and technological activities, deep popularisation of science is a subdivision of popularisation of science in China's new era, which focuses on the mental rooting and far-reaching dissemination of citizens' scientific and technological literacy. It is characterised by four types of features: the generalisation and infiltration of scientific thinking in terms of connotation; the coordination of "point" depth and "surface" expansion in terms of content; the internalisation of scientific and technological methodology and knowledge-acquisition ability rather than knowledge accumulation in terms of boundaries; and the transfer of scientific and technological ideas and paradigms into the minds of the citizens. In terms of objectives, the aim is to immerse scientific and technological ideas and paradigms in the behaviour of the recipients.

5. Conclusions

In the past 5 years, the reform of engineering physics curriculum has been practiced by 30,000 students in our university, and has been respected by 15 engineering majors of military-industrial background - attractive, high satisfaction of teachers and students, and has supported 13 majors in the certification of engineering majors. Its experience and achievements have been promoted in more than ten universities and social institutions, and 12 academicians and national "Ten Thousand People Plan" teaching masters have made characteristic and promotional evaluations, and have been reported by 8 provincial and national media, and a series of effective scientific exploration has been carried out.

Discovered 30 "physics-military-calligraphy" ideological elements with the heritage of the University, embodied in the "add interesting spices" of the provincial master teacher demonstration course (University Physics), a strong reaction among teachers. The awards for various university students' scientific and technological activities supported by the Institute of Fundamental Physics have reached 30%, twice as many as eight years ago, and 8% of the students are pursuing postgraduate degrees from prestigious schools. The course has won 15 honours at the provincial and national levels in Shaanxi.

The *Chinese University Physics Competition* (CUPT) supported by the course was reported by *Shaanxi TV*, *Shaanxi Daily* and other provincial media in 2018. 2021, the backbone teachers of the course participated in the Teaching Sharing Activity for Winning Teachers of Classroom Teaching Innovation Competition sponsored by the Department of Education of Shaanxi Province of China and *XUETANG* Online, with 4,000 online learners. There were 4,000 learners, and they had in-depth exchanges with teachers of 11 colleges and universities both online and offline. In 2020-2023, the course leader will promote physics curriculum construction and in-depth science popularisation of physics through "*365 Master Teachers Online*", with a cumulative total of 9,850 people paying attention to it.

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