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Teaching Quantum Mechanics Content in General Physics based on Online Courses

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Abstract: As one of the fundamental theories of physics, quantum mechanics is a major fusion of classical and modern physics and has great potential for development. With the continuous reform of higher education in China, the curriculum structure of engineering students has also changed. The phenomenon that classical physics occupies too high a proportion in traditional physics teaching is more prominent, and quantum physics occupies a lower proportion in physics teaching. This paper discusses how to strengthen and deepen the content of quantum physics in general physics teaching, based on online courses, to overcome the difficulties of insufficient credit hours and to build a good infrastructure for training quantum science and technology talents.

Keywords: Online-course; Quantum mechanics; Teaching strategies

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1. Teaching difficulties in quantum mechanics content in general physics

Quantum mechanics is a fundamental theory that studies matter, energy, particles, and the interactions and laws between them. It involves a series of basic concepts in physics such as the "microscopic world," "material composition," and "energy phenomena," and its applications are quite extensive. The development of medical imaging, nanoscience, laser physics, and the semiconductor field is all based on quantum principles. Quantum information technology (quantum computers, quantum encryption, and quantum entanglement) is a current hotspot. The content of quantum mechanics has always been an important part of university general physics teaching. Teachers should analyze and compare the importance of quantum physics from a professional perspective, help students understand the connections and differences between quantum physics and classical physics, and enhance students' awareness of quantum mechanics and its significance for the development of other disciplines. However, due to various reasons, the quantum mechanics section faces great difficulties in general physics teaching.

Firstly, it is determined by the characteristics of quantum mechanics itself. The way quantum mechanics understands the physical world and perceives physical reality is fundamentally different from classical physics, with a radical change [1]. This requires us to abandon the classical physical images formed over a long period and adopt new concepts of quantum mechanics to understand experimental results and explain experimental phenomena, causing various difficulties in teaching and learning [2].

Secondly, the study of quantum mechanics requires the use of a lot of mathematical knowledge, such as partial differential equations, complex functions, and linear algebra, which most students have not mastered proficiently, further increasing the difficulty of teaching and learning. Combined, these two reasons result in the fact that in current university general physics textbooks, the proportion of quantum mechanics content is not high, tends to be introductory, and avoids content with difficult and complicated calculations [3]. The last important difficulty is the insufficient teaching hours. In 1999, Mr. Zhao Kaihua called for setting the number of physics hours in engineering colleges to no less than 300 [4]. Now, the number of physics hours in general colleges and universities is around 100, and some have less than 80. The teaching content has been repeatedly reduced, and the proportion of quantum mechanics is extremely small. The limited classroom teaching time makes it difficult to explain the inherently difficult concepts and theories clearly, basically reducing it to an introduction to the history of quantum mechanics or popular science of quantum mechanics. Moreover, a considerable number of colleges and universities do not specifically offer quantum mechanics in related professional courses that require basic knowledge of quantum mechanics, such as optoelectronics, materials, and semiconductor technology. Relying solely on the “introduction” to quantum mechanics in general physics, it is hard to imagine how students can truly understand the relevant content and learn the corresponding professional courses well.

Of course, we do not hope to introduce the content of physics majors in general physics teaching, nor do we expect students to master complicated calculations (although there is a widely circulated saying that one cannot understand quantum mechanics without calculation - “shut up and calculate”). However, it is still possible to clarify the basic concepts and theoretical framework of quantum mechanics based on an “introduction” [5].

2. Teaching based on the SPOC model

To address issues in quantum mechanics teaching, such as “insufficient course hours”, “weak mathematical foundation,” and “low student interest leading to poor results,” the Internet has brought new opportunities for the development of traditional education. In the teaching of quantum mechanics-related content in general physics, we can fully leverage the advantages of the Internet to improve classroom teaching efficiency and effectiveness, and promote teaching reform and innovation through effective means. The reform of teaching quantum mechanics content in general physics courses based on the SPOC model combined with the PBL (Problem-Based Learning) teaching model is a promising approach worth exploring.

SPOC refers to a blended teaching model that combines online and offline learning. It integrates online resources from in-school teachers with classroom teaching. Through online teaching videos, reference materials, online assignments, quizzes, and other teaching resources, students first learn independently online. Then, they engage in face-to-face discussions, question-and-answer sessions, experiments, etc., in the classroom. Finally, offline assessments are conducted to complete the teaching process. PBL, on the other hand, is a student-centered learning model. With the assistance of teachers, students plan, implement, and self-evaluate their learning. Teachers allow students to select a research topic based on their interests and abilities, then collect information, explore, and discuss the topic.

In combination with the content of quantum mechanics courses, knowledge units are decomposed, and short teaching videos (5–15 minutes) are recorded. The video content should cover basic knowledge points, basic concepts, basic principles of the course, especially those contents that require more time in class, such as introduction to mathematical foundations, theoretical derivations, and explanation of exercises. Providing these through online mode helps to streamline classroom teaching time and allows students to watch repeatedly for better absorption and understanding. Teaching syllabuses, lecture notes, practice questions, reference materials, and resource libraries are provided as support for the course. The establishment of quantum mechanics concepts can be explained from the perspective of the history of science to help students understand [6]. In the past, due to time constraints, it was difficult to introduce the basic concepts of quantum mechanics and the context of theoretical development in detail. Now, popular science articles and literature can be provided online for interested students to read. Directly presenting a concept or theory to students is completely different from guiding them to observe and appreciate how physics masters established and completed their work in the long river of history in terms of the aesthetic experience. It is like crossing the Qinling Mountains: taking a tunnel is certainly fast, but climbing the winding mountain roads allows you to enjoy more magnificent scenery. In addition, there are many corresponding achievements in the visualization research of quantum mechanics [7]. Games developed to help understand quantum theories can provide relevant resources or access links in online courses to help students establish physical images and understand related content.

SPOC requires students to first conduct online autonomous learning, and the premise of guiding and motivating students to learn online is to give them a problem or project to complete. The problems and projects need to be carefully designed, considering dimensions such as stimulating students' interests, covering corresponding knowledge points of the course, the difficulty of the problems, and being close to applications and cutting-edge developments. Through collecting and reading materials, watching and thinking about course knowledge point videos, students return to offline classroom teaching to communicate and share with classmates and teachers about the questions and gains in online learning, so as to truly understand and master the course content.

3. Teaching examples

Laser technology is one of the most significant scientific achievements of the 20th century. In traditional general physics textbooks, the quantum mechanics section usually covers the principles of lasers. However, due to time constraints in actual teaching, the content often has to be abbreviated, resulting in only brief introductory explanations or being assigned as reading materials for students. In Mr. Zhao Kaihua's works, the physical basis of laser technology is given a prominent position. We have attempted to use online courses to provide a brief introduction to the quantum mechanical principles of lasers without increasing classroom hours, and to guide students in understanding relevant cutting-edge developments [8].

As shown in **Figure 1**, this course design consists of two parts: approximately 40 minutes of online learning and 45 minutes of offline learning. The first dashed box represents the online learning section. After studying the content related to Bohr's hydrogen atom energy level structure, students are guided to think about the developments and applications brought about by energy level theory. Corresponding materials are provided online for students to read and reflect on, such as a brief introduction to the development history of lasers (from Einstein's proposal of laser theory to the actual realization of lasers), China's contributions to laser technology, and the development of modern laser technology and its applications in industrial production. Two short teaching videos on spontaneous emission, stimulated emission, and the basic principles of lasers are produced for students to learn basic concepts and theories.

In classroom teaching, on the premise that students have mastered the basic knowledge, they are divided into groups to present their answers to the guiding questions and engage in mutual "defense." Then, possible

Question: What developments and applications have emerged from the understanding of the (hydrogen atom) energy level structure?	Absorption spectrum (technical principle, dark lines are not completely “black”)	Raman spectral analysis and its applications (chemistry,biology, semiconductor)
Energy level transition Absorbing photons Emitting photons (search for and read relevant materials)	Emission spectrum Spectral analysis (visible light – electromagnetic wave) Substance analysis – discovery of isotopes	Calculation, hypothesis, first - principles
Ground state of atom – two ways to excited state Electron collision (neon lamp) Photon absorption (Video explanation: 8 minutes)	Comparison with Compton effect. In the Compton effect, photons can only lose part of their energy. For stimulated emission, the incident photons must have a certain amount of energy.	Not all energy level transitions will emit light – selection rule Material selection for LED, solar cell Cell efficiency (10-20%), maximum 47% in laboratory. The efficiency of plant photosynthesis is close to 100% ---explanation by quantum mechanics---application prospects
Laser: Light amplification caused by stimulated emission. Features: Monochromatic, coherent General excited state: 10^{-8}s Metastable excited state: 10^{-3}s Ground state Population inversion Three - level: Ruby Four - level: Helium - neon Animation demonstration of three - level and four - level excitation (Video explanation: 15 minutes)	Why can’t two - level be realized? How to create a metastable state? (Doping Cr^{3+} (trivalent chromium ion) in ruby) Comparison of the difficulty in achieving population inversion between four - level and three - level.	Expanded Knowledge, Sci - Tech Frontiers
Online Learning Part	In - class Discussion Part	

Figure 1. Course design for “Laser” content based on the SPOC model.

problems raised by students are addressed. Common typical questions include: What is the difference between a gas luminescence system and a laser? Why can a second-order system not produce a laser? How to achieve and understand population inversion? [9] These questions may be answered by the students themselves or may require the teacher to explain using semiclassical theory to help students form a complete physical picture. Finally, the focus is on discussing the related content of spectral analysis and laser principles. Striving to provide qualitative explanations without involving complex calculations, the aim is to enable students to understand and master their development history and related principles, as well as their applications in modern research and industry. Extended relevant content can also be provided for students with extra capacity to explore, playing a forward-looking role for students of different majors in their future professional course studies. For example, an approximate calculation used in the discovery of isotopes: the problem of electron motion can take the nuclear coordinates as the reference frame (approximately considering the nucleus as almost stationary), which is actually the Born-Oppenheimer adiabatic approximation in the development of first-principles, and first-principles play an important role in modern materials science and condensed matter physics research. Another example is that in third-order and fourth-order models, after achieving population inversion, it is found that the transition between two certain energy levels does not “emit light.” This involves selection rules and requires more basic knowledge of quantum mechanics (such as concepts like quantum numbers) and calculations. In practical applications of materials science, this relates to the selection of materials for LEDs and solar cells. Furthermore, a comparison can be made between the efficiency of solar cells and that of plant photosynthesis, and the high efficiency of plant photosynthesis can also be explained using quantum mechanics, which in turn can help us design high-efficiency solar cells [10].

Combining question guidance with mixed online and offline teaching, the detailed introduction to historical development, basic principles, and application frontiers can basically enable students to master the basic concepts, theories, and methods of this content. It also allows them to understand specific applications in scientific research experiments and industrial production, which would be difficult to achieve in traditional classroom teaching, where it is hard to convey such rich content within a limited time while guiding students to think about related issues [11,12]. The advantage of the SPOC model lies in awakening students' problem awareness, guiding them to engage in research-based learning, and improving their ability to analyze and solve problems.

4. Assessment and evaluation

Students will be given a comprehensive score based on their submitted assignments and performance in classroom teaching activities. The method of classroom questioning can enable students to conduct in-depth discussions around a certain knowledge point. In group discussions, students can improve their understanding and mastery of classroom knowledge through discussions, and it can also increase communication between teachers and students. At the same time, grouping students for discussions allows for better division of labor and cooperation, cultivating the ability of unity and collaboration among group members. During group discussions, teachers should keep track of students' mastery of the knowledge point at all times to make timely adjustments and improvements.

By monitoring and analyzing the teaching process of teachers, we can understand students' learning situation of the core content and other contents of the course. Through discussions and exchanges with students, we can learn about students' problems and difficulties in the course learning process, their ability to solve problems, and their learning interests. Evaluation is carried out according to the knowledge points and key points included in the course design. The key contents include whether the course concepts are clear; whether the course theories are solid; whether the classroom participation meets expectations; and whether students have the basic ability to solve practical problems [13]. For classes with low participation rates (below 50%) and some classes with relatively low participation rates (above 30%), targeted teaching reflections should be conducted.

5. Achievements and reflections

In the actual teaching process, the author compared two teaching classes, one adopting the SPOC model and the other adopting the traditional classroom teaching model. Although there was little difference in the written test scores in the final assessment, in the class taught by the SPOC model, students' classroom participation was significantly higher, the classroom atmosphere was active, and their interest in physics class was significantly higher than that in the traditional classroom teaching class. Students had a deeper understanding of some contents of quantum mechanics, laying a solid foundation for their further study in related fields [14,15].

Of course, the SPOC model requires the active participation of students. It can be found through the records of the course platform that not all questions can get positive responses from students, and not all students can actively participate in online course learning. On the one hand, teachers need to carefully design questions and projects to improve participation interest and reduce participation thresholds; on the other hand, it is also necessary to convey the importance and necessity of research-based learning to students in teaching. To sum up, it is feasible and beneficial to strengthen and deepen the teaching of quantum mechanics content in general physics teaching by using online courses.

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References

[1] Karakostas V, Hadzidaki P, 2005, Realism vs. Constructivism in Contemporary Physics: The Impact of the Debate on the Understanding of Quantum Theory and Its Instructional Process. Science & Education, 14(7–8): 607–629.

[2] Wang S, Zhu G, 2020, A Brief Review of Quantum Mechanics Teaching Research in Physics Education Research. Physics and Engineering, 30(6): 48–55 + 60.

[3] Krijtenburg Lewerissa K, Pol HJ, Brinkman A, van Joolingen WR, 2017, Insights into Teaching Quantum Mechanics in Secondary and Lower Undergraduate Education. Physical Review Physics Education Research, 13(1): 010109.

[4] Chen J, Zhao K, Wang Z, 1999, Facing the 21st Century, It Is Urgent to Reconstruct Engineering Physics Education in China. Engineering Physics, 1999(5): 1–3.

[5] Müller R, Wiesner H, 2002, Teaching Quantum Mechanics on an Introductory Level. American Journal of Physics, 70(3): 200–209.

[6] Tian G, 2011, Some Experiences on Quantum Mechanics Teaching for Undergraduates. College Physics, 30(3): 52–58.

[7] McKagan S, 2008, Developing and Researching PhET Simulations for Teaching Quantum Mechanics. American Journal of Physics, 76(4): 406–417.

[8] Deng L, Chen D, Guo Y, 2023, Research on Optimization of Quantum Mechanics Teaching Content under the Background of New Engineering. Physics and Engineering, 33(2): 88–92.

[9] Liu H, Yi X, 2024, Exploration and Practice of Blended Teaching of Quantum Mechanics Based on the Integration of Science and Education. Journal of Higher Education, 10(33): 115–118.

[10] Liang Z, Wang G, 2024, Reform and Practice of Digital Teaching in Quantum Mechanics Course. Higher Education in Chemical Engineering, 41(5): 47–52.

[11] Liu Y, Lu H, Peng S, 2023, Exploration and Practice of Ideological and Political Teaching Reform in Atomic Physics Course. Journal of Guizhou University of Engineering Science, 41(3): 133–138.

[12] Hao Y, Zhang X, Wang C, et al., 2022, Exploration and Practice of Atomic Physics Teaching Reform under the Background of Curriculum Ideology and Politics. Journal of Xingyi Normal University for Nationalities, 2022(3): 74–78.

[13] Zhu X, Wang G, 2025, Exploration of Ideological and Political Teaching Strategies in Quantum Mechanics Course. Creative Education Studies, 13(4): 649–654.

[14] Wang Z, Yao L, Hou Y, 2024, Thoughts and Discussion on Curriculum Ideology and Politics in Quantum Mechanics. Encyclopedia Forum Electronic Magazine, 2024(3): 176–178.

[15] Zhou R, Li D, Qu B, 2021, Research and Practice on Informationized Teaching Reform of "Quantum Mechanics" Course. Education and Teaching Forum, 2021(38): 4.