Development Strategy for SPOC Digital Textbook of College Physics Based on Course Knowledge Graph

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ABSTRACT

Digital textbooks are an integral part of educational digitization and a vital direction for future textbook construction. Upon analyzing the digitalization needs of college physics courses, this paper proposes a strategy for the development of SPOC digital textbooks based on course knowledge graphs. This aims to optimize textbook structure and enhance personalized learning experiences for students. The paper first examines the current challenges in college physics courses and highlights the potential application value of course knowledge graphs. A theoretical framework is then established to guide the construction of knowledge graphs and the development of SPOC digital textbooks. Finally, the paper discusses the implementation steps and challenges of digital textbook development, and forecasts directions for future research.

Keywords: *Course knowledge graph, SPOC, Digtial textbooks, Physics instruction.*

1. INTRODUCTION

With the rapid development of big data and artificial intelligence, digital instruction has become an important trend in the field of education. Under the tide of educational digital transformation, as an essential element of course implementation, textbooks should leverage the benefits of internet technologies to innovate their formats. The construction and utilization of digital textbooks are imperative to propel the educational digital transform [1]. Under this background, the SPOC (Small Private Online Course) model, as an emerging teaching paradigm, is increasingly becoming mainstream, garnering attention and recognition. SPOC-based blended learning courses, emphasizing personalized learning and interaction, better fulfill student learning needs, providing a necessary content framework for the construction and development of digital textbooks. [2, 3]

Knowledge graphs represent a significant technological innovation within the computer science field, employing graph structures for knowledge representation and enabling automated knowledge acquisition and application through association and inference techniques, thus offering rich personalized services to learners [4, 5]. Course knowledge graphs, a specific application of knowledge graphs in education, have extensive use cases in digital learning. They can integrate course knowledge points and resources, providing a systematic and clear knowledge framework; when integrated with teaching platform analytics and learning tracks, they extract features such as mastery status, knowledge dimensions, and areas of weakness, recommending tailored learning materials to students. Furthermore, course knowledge graphs also provide teachers with better basis for curriculum design and process evaluation [6, 7].

With the maturation of underlying technologies and the diversification of application scenarios, blended learning has become the norm in course instruction. The integration of knowledge graph technology into the development of SPOC digital textbooks holds significant value and positively contributes to the digitalization of course teaching. This paper analyzes the demands and challenges in the construction of digital textbooks for college physics courses and proposes strategies for developing SPOC digital textbooks utilizing course knowledge graph technology to advance the development of digital education and instruction.

2. NEEDS ANALYSIS FOR THE CONSTRUCTION OF COLLEGE PHYSICS DIGITAL TEXTBOOK

2.1 Problems and Challenges in Course Instruction

Firstly, our university's physics courses are taught in large classes, resulting in limited opportunities for teacher-student interaction which fails to meet the individualized learning needs of students with varying academic backgrounds. During self-study, students may find some concepts difficult to grasp or require more examples to solidify their understanding. However, traditional paper-based textbooks are unable to offer the personalized and diverse learning resources needed. Variations in knowledge representation and content organization across different publishers' textbooks lead to disjointed student learning experiences.

Secondly, traditional textbooks are not suited to modern online teaching methods, providing a unidirectional knowledge transfer that lacks interactivity and adaptability, making it difficult to stimulate student interest and motivation. Although some publishers have released digital textbooks, most simply replicate the print content electronically, with a relative scarcity of multimedia materials. Overall, with the general reduction in college physics course hours, the utilization rate of paper textbooks is low and students' willingness to purchase them has decreased—a trend that is detrimental to students' fundamental knowledge and skill development.

2.2 Student Learning Needs and Habits

Under the student-centric teaching philosophy, it's crucial for instructors to understand students' learning needs and habits. With the reform of the college entrance examination system, some students have not systematically studied physics during their secondary education, resulting in a weak foundation and a sense of apprehension towards college physics courses. Addressing how to learn physics from the ground up has become a primary requirement for these students.

In today's digital age, students increasingly rely on online resources to access learning materials. They are accustomed to acquiring knowledge through video platforms and prefer using digital tools for learning and communication. Furthermore, with a student body primarily focused on "Chemistry", there is a common tendency towards rote memorization, which is detrimental to the study of physics and the cultivation of logical thinking skills. According to the curriculum, to achieve higher cognitive dimensions of teaching objectives, students need to deepen their understanding and application of knowledge through practical operations and case analysis.

2.3 The Urgency of Developing Digital Textbook for Physics Course

Given the aforementioned analysis, there is a critical need for the construction of digital textbooks for college physics courses. Firstly, digital textbooks can better meet the individualized learning needs of students by utilizing artificial intelligence to construct personalized learning paths and recommendation systems. This provides learning resources and plans tailored to students' requirements and interests [8]. Secondly, digital textbooks offer abundant and diverse learning resources, including videos, animations, and interactive experiments, to more effectively present physical concepts and principles, thereby stimulating students' interest and initiative in learning [9]. Additionally, digital textbooks are timely and can be updated swiftly to reflect the latest scientific research and developmental trends, offering students more forward-looking and practical knowledge. Lastly, through the use of SPOC platforms, digital textbooks can support interactive learning and practice-oriented design, allowing students to apply physics knowledge in practice through virtual experiments and case analyses, enhancing their understanding and mastery of the subject.

3. COURSE KNOWLEDGE GRAPH

3.1 Overview of Course Knowledge Graph

A knowledge graph is a graphical data structure used to represent and store entities and their interrelationships, designed to organize and present various types of knowledge from the real world in a structured format. The core components of a knowledge graph include entities, attributes, and relationships [7]. Course knowledge graphs typically focus on constructing around core course knowledge points. As a foundational educational resource, the course knowledge graph models course knowledge and its complex relationships, form a knowledge network with interconnected nodes and inclusive sequences of knowledge points. It aids students in establishing personal learning pathways and forming a comprehensive course knowledge system, enhancing learning efficiency and quality, thereby meeting the individualized learning needs of learners [6].

3.2 The Role of Course Knowledge graph in College Physics SPOC Teaching

The application of knowledge graphs in the education field has seen some success. SPOC platforms and learning systems like ‘Chao Xing’ and ‘Yu Ke Tang’ are using knowledge graph technology to provide personalized learning guidance and intelligent study companions, helping students to better tailor their study plans and search for relevant learning resources. Furthermore, research institutions and schools are beginning to apply knowledge graph technology to course design and teaching assessment to enhance teaching outcomes and student satisfaction [10]. Whereas traditional SPOC resources were organized according to course chapters, integrating course knowledge graphs into SPOC course design can more clearly demonstrate the overall framework and interrelations among knowledge points. Therefore, utilizing knowledge graph technology to optimize college physics teaching has practical significance and potential benefits. Firstly, knowledge graphs help integrate and present the knowledge network of college physics, enabling students to clearly understand physics concepts, laws, and principles and apply them to real-world problems in their professional field. With the visual representation provided by the course knowledge graph, students can better comprehend the dependencies and derivative relationships between different physics modules, thus increasing their interest and proactivity in learning. Secondly, knowledge graphs can also aid SPOC platforms in constructing personalized learning path, providing learning resources and plans that match students' professional and interest profiles based on their unique characteristics.

3.3 Construction of the Course Knowledge Graph

When developing a knowledge graph for a physics course, initially employ manual methods to construct the course ontology. Expert educators should comprehensively organize and categorize course knowledge points based on teaching syllabi and educational objectives. This includes a comprehensive arrangement and categorization of fundamental physics concepts, laws, formulas, and principles of experiments, structured according to logical relationships and intrinsic connections. The accuracy and relevance of resources are higher with manual construction, which necessitates systematic top-level design by the teaching team. The construction process also needs to take into account the relation between course resources, the teaching process, and knowledge points, particularly the alignment of physics knowledge points with subsequent professional courses, demonstrating the curriculum system's framework. Therefore, the course knowledge graph can also serve as part of a broader curriculum group knowledge graph, extending the linkage of knowledge points beyond the course itself. Such construction assists learners in clearly understanding the structure of the knowledge system within physics course, as well as its relation to subsequent professional course studies, contributing to improved student learning efficiency and depth.

4. FRAMEWORK FOR DIGITAL TEXTBOOK CONSTRUCTION BASED ON KNOWLEDGE GRAPH

4.1 Knowledge Graph Construction for Educational Resources

With the advancement of internet technology, digital textbooks have evolved into multimedia and rich media formats, trending towards becoming teaching platforms and systems [11]. They present instructional content through digital resources such as text, audio, video, and animation. By applying knowledge graph techniques to SPOC educational resources, dispersed resources can be managed and utilized more efficiently. The knowledge graph links syllabus, knowledge units, and educational resources, creating a structured framework for digital textbooks as illustrated in “Figure 1”. The knowledge graphing of SPOC resources involves annotation, categorizing, and linking resources, enabling students to quickly locate the learning resources they need and select them based on personal learning needs and interests, moving away from the traditional method of searching through textbook contents. Additionally, instructors can use the knowledge graph to organize and plan teaching resources more effectively, resulting in a more systematic and diversified teaching content.

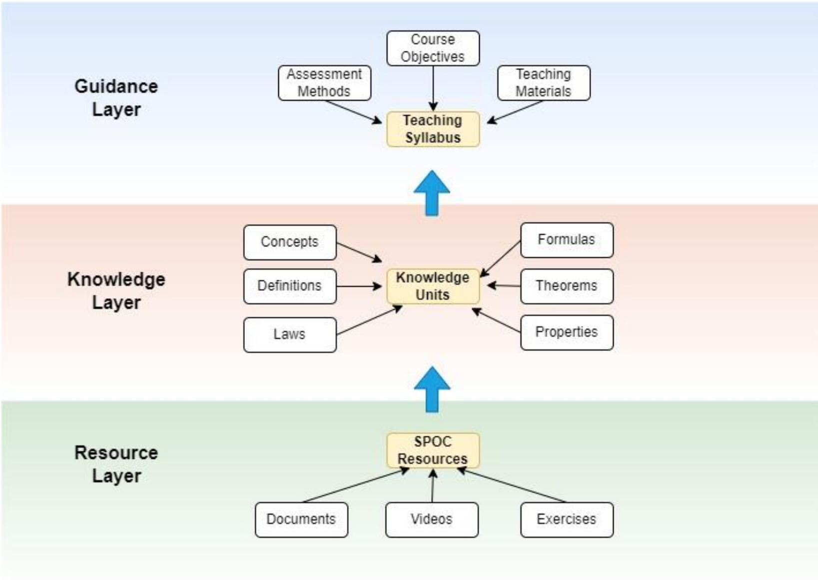

Figure 1 Framework of digital textbook structured by knowledge graph.

4.2 Personalization of Learning Path

Digital textbooks can adopt various forms of digital resources tailored to different teaching objectives, thereby achieving educational goals more efficiently. Entity attributes in knowledge graphs can be categorized into different levels, such as knowledge points ranging from lower to higher cognitive perspectives: memorization, understanding, application, analysis, synthesis, evaluation. For lower-order goals like memorization and understanding, graphics and text-based courseware may be used, while higher-order knowledge points may involve case analysis questions or virtual experiments [12]. Course knowledge points can be tagged with labels such as key points, difficult points, and examination points, which guide the design of various media presentation forms. Students with different learning styles and backgrounds can choose from diverse digital resources based on the course knowledge graph to achieve educational objectives. By analyzing students' learning history and status through the digital textbook, the system can recommend the most suitable learning path based on the knowledge graph, enabling students to learn physics more efficiently.

4.3 Interactive Learning and Practical Component Design

Digital textbook construction based on knowledge graph should have interactive learning and practical components. Through the SPOC platform, digital textbooks can offer students interactive human-computer interfaces, knowledge search tools, and teacher-student interactive communication channels, supporting peer-to-peer and instructor-student discussions, thus enhancing participation and proactivity in learning. For instance, when teaching about wave mechanics, a link to PhET's virtual experiments (https://phet.colorado.edu/en/simulations/waves-intro) could be embedded within the SPOC platform, allowing students to understand physical concepts and wave properties through simulation. The integration of physics simulation experiments enhances the interactivity and extensibility of digital textbooks, with specific simulation operations illustrated in "Figure 2".

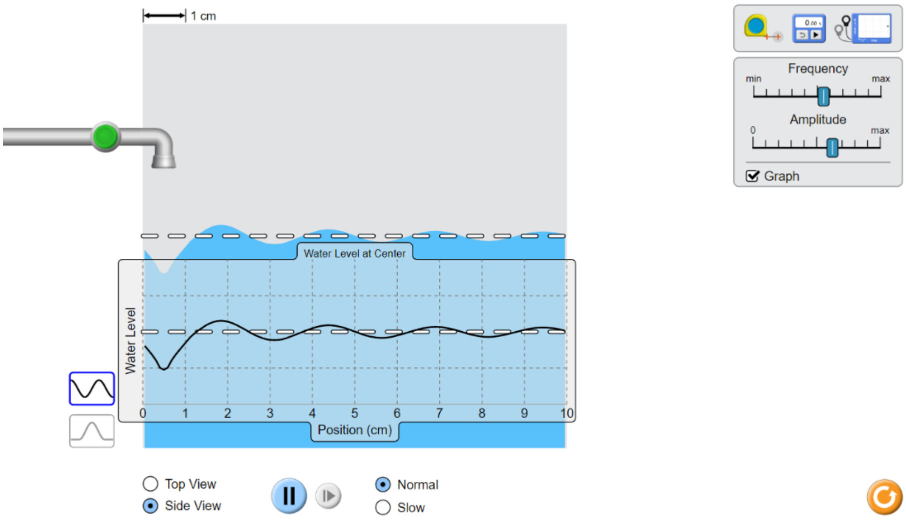

Figure 2 Learning about waves with PhET simulation.

5. DEVELOPMENT STRATEGY FOR DIGITAL TEXTBOOKS

5.1 Challenges in Advancing Digital Textbooks

Digital textbooks expand the spatiotemporal boundaries of student learning, fostering the co-creation and sharing of quality educational resources and opening up unprecedented possibilities for innovation in teaching methods. However, there are challenges in content management, technological development and application during the advancement of these resources [9]. For instance, the openness, interactivity, innovativeness, and diversity of media forms in digital textbooks significantly complicate content regulation and review [13].

Furthermore, proprietary digital textbook platforms from publishers often lack the necessary flexibility and openness, failing to ensure effective interfacing and sharing of digital resources among instructors, and interaction between teachers and students can be weak. Additionally, a key performance indicator for digital textbooks is how effectively foundational courses like physics can be seamlessly integrated with subsequent specialized courses. The full potential of digital textbooks is only realized when foundational knowledge is seamlessly integrated with professional applications, thereby fostering students' in-depth cognitive development and reinforcing their professional foundations.

5.2 Development Approach for Digital Textbooks Using SPOC Platforms

Courses on the SPOC platform are characterized by their school-based and flexible nature, and their digital resources and data management capabilities provide a necessary foundation for the development of digital textbooks. The combination of knowledge graph with digital resources can effectively address challenges in content review. The development process and strategy are as follows: First, based on traditional paper-based physical textbooks and syllabi, course knowledge is systematically processed to construct a physics course knowledge graph, integrating teacher expertise, knowledge point interconnections, and learning pathways to facilitate self-directed learning [8]. Furthermore, the course knowledge graph can be built utilizing the existing knowledge graph module on mainstream SPOC teaching platforms, saving development time and costs for the teaching team and supporting students in self-study and personalized learning paths. By utilizing the existing MOOC resources, video resources, and literature resources on teaching platforms, instructors can establish a systematic and visual network of knowledge point connections. This development approach creates a three-tier resource construction process of "teaching team → school-level management → platform review" to ensure effective supervision and review of digital textbook content. Moreover, the knowledge graph entities are derived from traditional published materials and the platform's extensive MOOC resources, ensuring content accuracy and reliability. Utilizing the SPOC teaching platform server deployed within the school can significantly reduce the technical difficulties and related costs of constructing knowledge graphs and developing digital textbooks. In the construction of digital textbooks, the leading role of instructors should be fully leveraged, as their practical application is essential to uncover the intrinsic value and effectiveness of digital textbooks.

6. CONCLUSION

Digital textbooks are pivotal to the digital transformation of education and have become the cornerstone of digital teaching environment. They redefine traditional teaching and learning models and foster a new digital learning ecosystem, supporting blended teaching methods. Digital textbooks for college physics on the SPOC platform can enhance students' self-learning and scientific inquiry abilities. The construction of course knowledge graph tailors digital resources to be more targeted and systematic. To create high-quality digital textbooks, concerted efforts are needed to improve the intelligence and standardization of digital textbook platforms. Advancing digital education reform is a demand of our era, and thus, frontline teachers should leverage the construction and application of digital textbooks to improve their digital teaching capabilities.

AUTHORS' CONTRIBUTIONS

Yan Sun put forward ideas and wrote the paper, and Hongyan Zhang contributed to revising and editing.

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