Digital heterogeneity of higher education teaching materials

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Abstract In the digital age, higher education is undergoing significant transformations, with textbook digitization becoming a crucial focus. The "Outline of the Education Power Construction Plan (2024–2035)" underscores the urgency and importance of digital and intelligent transformation in textbooks. By analyzing the results of the National Outstanding Textbook Selection, this study explores the disciplinary distribution of digital textbooks in Chinas higher education system. The research reveals notable heterogeneity in award-winning digital textbooks across disciplines: medical and natural sciences demonstrate higher award rates, while humanities and agricultural sciences lag behind. Additionally, there are distinct preferences in award-winning formats—natural sciences favor "paper + online courses", whereas humanities and social sciences prefer "paper textbooks with digital teaching resources". The analysis suggests that disciplinary characteristics, developmental needs, and technological advancements are key factors influencing award distribution. Therefore, the development of digital textbooks in higher education requires differentiated strategies: tailoring initiatives to disciplinary features, establishing discipline-oriented standards, enhancing resource support, improving evaluation mechanisms, elevating textbook quality, promoting interdisciplinary collaboration, and stimulating collaborative innovation.

Index Terms Higher education, Teaching materials, Digitization, Heterogeneity

I.   Introduction

In todays digital and intelligent era, information technology is evolving at an unprecedented pace and deeply integrating into all sectors of society. The higher education sector has also undergone profound transformations. The report from the 20th National Congress of the Communist Party of China explicitly proposed advancing educational digitalization and strengthening textbook development and management, charting a clear path for higher educations digital transformation. The "Outline of the Plan for Building a Strong Education Nation (2024–2035)" further emphasizes "accelerating the digital and intelligent transformation of textbooks", highlighting the urgency and significance of developing digital teaching materials in current educational development [1].

   As the premier award in Chinas textbook development sector, the inaugural National Textbook Development Award reflects the current state of higher education materials nationwide. Through descriptive analysis of digital textbooks in higher education from this inaugural edition, we can examine the current status, achievements, and future trends of digital textbook development in Chinese universities, providing valuable insights for contemporary initiatives. Considering disciplinary diversity, this study conducts disciplinary-specific research to analyze practical challenges and existing issues in digital textbook development across different fields. By identifying both common requirements and unique characteristics shared by various disciplines, it establishes a solid foundation for targeted digital textbook development strategies.

II.   The disciplinary distribution of the award-winning digital teaching materials

According to the "Undergraduate Program Catalog for Regular Higher Education Institutions (2024)" released by the Ministry of Education, Chinas higher education system primarily comprises 13 disciplinary categories: philosophy, economics, law, education, literature, history, natural sciences, engineering, agriculture, medicine, management, and art. As the military academies evaluation for the inaugural National Textbook Development Award was conducted independently, the statistical data in this study does not include "Military Science".

II. A.   *Award-winning digital teaching materials in different disciplines*

Through statistical analysis of survey data, this study reveals the following characteristics in award-winning digital textbooks across higher education disciplines: First, significant disciplinary disparities exist in digital textbook awards. In terms of quantity, engineering leads with 56 award-winning textbooks, while philosophy has only 2, indicating substantial differences

in award-winning numbers between disciplines. This highlights uneven development in digital textbook construction and promotion across academic fields. Second, medical and natural sciences demonstrate higher award-winning rates. Medical disciplines account for 84% of all award-winning textbooks, followed by natural sciences (60%) and economics (63%). The dominance of these disciplines suggests their mature application of digital teaching materials that better align with pedagogical needs, resulting in broader recognition and adoption. Third, humanities and agriculture lag behind in digital textbook development. Humanities and agriculture each hold only 33% and 27% of award-winning textbooks respectively. This low representation indicates limited digital textbook adoption in these fields, necessitating enhanced development and promotion to meet the demands of educational informatizationPotential (see Table 1).

Table 1: Number and proportion of award-winning digital teaching materials in 12 disciplines nationwide

Disciplinary categories	Number of digital teaching materials awarded	Number of award-winning books	The ratio of the number of digital teaching materials to the total number of teaching materials awarded
engineering	56	120	47%
medical science	37	44	84%
natural science	31	52	60%
management	23	40	58%
law	13	25	43%
economics	12	19	63%
literature	10	30	33%
education	8	15	53%
art	8	16	50%
history	4	7	57%
agronomy	3	11	27%
philosophy	2	4	50%
amount to	207	383	54%

II. B. *Types of awards for digital teaching materials in different disciplines*

Currently, there is no unified or clear definition and construction standards for digital textbooks both domestically and internationally. With the further development and application of high technologies such as big data and artificial intelligence, the concept of digital textbooks will continue to evolve dynamically over a considerable period. At present, most publishers recognize digital textbooks as either a combination of traditional paper-based materials and digital resources, or purely digital materials. These digital resources integrate next-generation information technologies like artificial intelligence, virtual reality, and augmented reality, presented through internet and mobile platforms. Based on this perspective, this study categorizes digital textbooks into two major types: "paper-based textbooks with digital resources" and "pure digital textbooks". The latter refers to completely digitized materials that are entirely separate from paper-based textbooks. The "digital resources" in "paper-based textbooks with digital resources" (hereinafter referred to as "paper+" textbooks) are primarily divided into two categories based on additional digital content: "digital teaching resources" and "online courses". The former includes courseware, exercises, case studies, and other content presented in formats such as audio, animations, videos, and images, accessible through various channels including "website access", "email submission", "QR code scanning", "app downloads", and "CD usage" (see Table 2).

As shown in table 2, to gain deeper insights into the award-winning digital textbooks across various disciplines nationwide, this study analyzed and compiled statistics on the quantity and types of award-winning materials. The findings reveal that in the category of mathematics and medicine—traditional natural sciences—the majority of award-winning digital textbooks adopted a "paper + online course" format. In contrast, six disciplines including engineering, management, economics, literature, education, and arts predominantly featured "paper textbooks supplemented with digital teaching resources". Notably, award-winning materials in humanities (law, history, philosophy) and agriculture predominantly adopted a "paper + digital teaching resources" format, with none utilizing the "paper + online course" model.

Table 2: Number and types of award-winning digital teaching materials by subject in China

Disciplinary categories	Number and proportion of different types of award-winning digital teaching materials								The difference between the number of textbooks with "paper + digital teaching resources" and the number of textbooks with "paper + online courses"
	Digital textbooks		"Paper + digital teaching resources" textbooks		"Paper + online course" textbook		Not indicated		
engineering	–		29	52%	22	39%	5	9%	13%
medical science	–		11	30%	21	57%	5	14%	–27%
natural science	1	3%	12	39%	18	58%	–		–19%
management	–		21	91%	–		2	9%	91%
law	–		13	100%	–		–		100%
economics	–		10	83%	1	8%	1	8%	75%
literature	–		8	80%	2	20%	–		60%
education	–		6	75%	1	13%	1	13%	62%
art	–		6	75%	–		2	25%	75%
history	–		4	100%	–		–		100%
agronomy	–		3	100%	–		–		100%
philosophy	–		2	100%	–		–		100%
amount to	1		125		65		16		

III. Motivations affecting the distribution of award-winning digital teaching materials

The previous analysis reflects that there are significant heterogeneity in the construction of digital teaching materials across different disciplines, which is related to various factors such as discipline characteristics, market demand and technological development. The following further discusses the driving forces behind these heterogeneity.

III. A. The influence of disciplinary characteristics on the distribution of digital teaching materials

As the primary vehicle for knowledge delivery, textbooks must prioritize content alignment in their design and development. While digital textbooks demonstrate innovative formats, they fundamentally remain educational materials that must precisely align with teaching objectives. Although offering greater diversity in presentation compared to traditional paper-based textbooks, digital materials consistently maintain a student-centered approach. Their core mission is to ensure students systematically and deeply grasp subject-specific knowledge, thereby establishing a solid disciplinary foundation. Consequently, the nature of academic disciplines significantly influences the quantity of digital textbooks produced [2].

In the research on knowledge structure and presentation methods, natural science disciplines such as physics, chemistry, and biology can vividly demonstrate complex scientific phenomena and experimental processes through digital means like virtual experiments and animated demonstrations. This undoubtedly attracts more developers to engage in the creation of digital textbooks. However, for humanities and social sciences disciplines like history and philosophy, whose knowledge content primarily focuses on textual descriptions and theoretical explanations, although multimedia resources can enrich teaching materials, such functions are typically limited to auxiliary roles and struggle to serve as substitutes. This constraint has, to some extent, hindered the widespread application of digital textbooks in these fields.

Moreover, the pace of knowledge updates in academic disciplines is another crucial influencing factor. Taking medical education as an example, students face a conflict between the extended study duration and the rapid evolution of medical knowledge. A textbook that remains in use for five years may already contain outdated content by the time students graduate, failing to meet clinical demands. In contrast, digital textbooks can rapidly update their content to effectively satisfy teaching requirements, which explains why there is relatively higher demand and development volume for digital materials in these fields. Conversely, traditional disciplines like mathematics and philosophy have more stable core knowledge systems, where printed textbooks adequately meet educational needs, resulting in less motivation for developing digital alternatives.

III. B. The influence of disciplinary needs on the distribution of digital teaching materials

Subject-specific demands significantly influence the development of digital textbooks, with publication volume serving as a key indicator for assessing these needs. The National Textbook Survey Platform for K-12 Education, established by the Office of the National Textbook Committee, provides comprehensive data on textbook production and usage across all educational levels through functions including data collection, information management, and query analysis. Based on this platform, this study identified 22,634 higher education digital textbooks published between 2019 and 202 4, with their disciplinary distribution patterns as follows Figure 1:
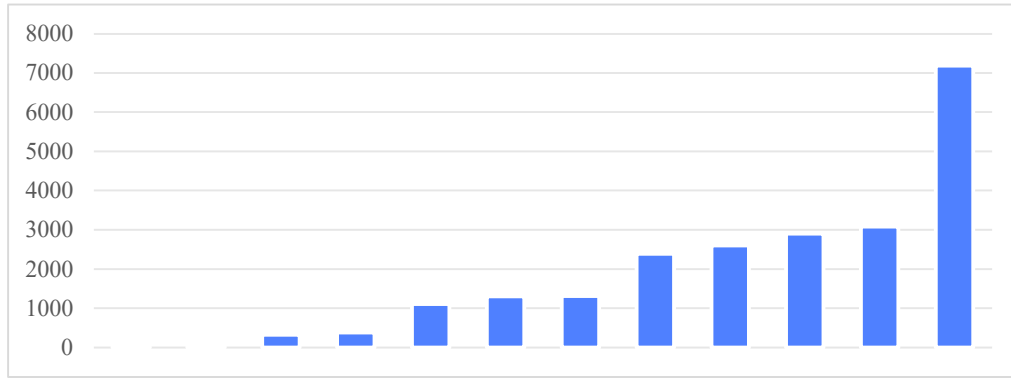
Figure 1: Discipline Distribution of Digital Textbook Publishing in Higher Education

Note: From left to right are engineering, literature, science, management, medicine, art, education, economics, agriculture, law, history and philosophy

The data clearly shows that engineering-related digital textbooks lead in publication volume, demonstrating the substantial teaching demands and diverse application scenarios of engineering disciplines in higher education. With rapid technological advancements, engineering-related fields such as engineering technology and information technology are constantly evolving, driving growing demand for digital textbooks. These digital resources can be updated promptly with cutting-edge technical case studies, effectively meeting both professional educational needs and students learning requirements.

Furthermore, the substantial publication of digital engineering textbooks may stem from concentrated resource investments in research and education within this field. Universities, research institutions, and publishing organizations emphasis on engineering education has led to increased funding, human resources, and technological resources being directed toward developing and publishing digital engineering textbooks. However, the relatively limited number of digital textbooks published for disciplines such as agronomy and art studies may reflect insufficient resource allocation in these fields. This could potentially impact teaching quality and talent cultivation in these disciplines, thereby constraining their development and innovation.

III. C. The influence of technological development on the distribution of digital teaching materials

Regardless of their format, digital textbooks must first serve as effective carriers for educational content. The core challenge in developing such materials lies in integrating academic subjects with digital technologies. On one hand, the substantial technical costs associated with creating digital textbooks for certain disciplines limit their quantity. Specifically, developing digital textbooks requires significant investments in human resources, material resources, and financial resources, including textbook compilation, digital production, and technological development. For complex academic subjects like abstract concepts in advanced mathematics or microscopic particles in physics, producing high-quality digital textbooks demands advanced technical expertise and specialized knowledge. This developmental complexity results in relatively limited quantities of digital textbooks for these disciplines [3].

On the other hand, the development of digital textbooks must fully consider their compatibility with different disciplines. The teaching content and methods across various subjects exhibit significant heterogeneity, with distinct priorities in functional requirements and resource demands for digital materials. For instance, science textbooks typically require more interactive experiments and simulation tools, while humanities textbooks place greater emphasis on integrating textual content with multimedia resources.

IV. Suggestions on Promoting the Construction of Digital Teaching Materials in Different Disciplines

IV. A. Implement differentiated construction strategies based on disciplinary characteristics

Higher education textbooks exhibit remarkable diversity through their rich and varied content. In developing digital textbooks, this characteristic must be fully recognized and integrated throughout all stages including design, development, distribution, application, and management. This requires a balanced approach to balancing universality and specificity – avoiding the pitfall of generalizing specific disciplinary cases or adopting a one-size-fits-all approach that ignores individual subject characteristics. Only through such comprehensive consideration can we effectively enhance the relevance, applicability, and feasibility of digital textbooks. Tailored strategies should be developed to accommodate different academic disciplines: Liberal arts programs should strengthen digital resource development by creating multimedia teaching materials like digital

literary adaptations and virtual historical scenarios to cultivate students humanistic literacy. Science programs need to enhance virtual experiment platforms that concretize abstract concepts through technology, aiding student comprehension. Engineering disciplines should deepen industry-academia-research collaboration, update textbook content, and design more hands-on modules to foster practical and innovative capabilities. Medical education must ensure the authenticity and safety of clinical case studies in digital textbooks while reinforcing medical ethics education to nurture responsible healthcare professionals [4].

IV. B. Develop discipline-oriented standards and standardize the construction of digital teaching materials

The digital textbook development sector currently faces a critical challenge: —— Non-uniform development standards. Disparities in technical approaches and standards adopted by different institutions result in incompatible versions of digital textbooks, hindering seamless integration with diverse educational platforms. This not only increases development complexity and costs but also severely impedes their widespread adoption across academic disciplines. To address this issue, the Ministry of Education and relevant authorities should proactively mobilize multidisciplinary experts including subject specialists and educational technologists. By establishing tailored standards based on the unique characteristics and specific needs of different academic fields, these guidelines should comprehensively cover key aspects such as content quality, technical specifications, interactive design, and security features. This ensures digital textbooks fully meet practical teaching requirements in various disciplines. For example, STEM-focused digital textbooks should explicitly specify technical details like formula accuracy, standardized chart creation, and authentic experimental simulations to guarantee students access to precise knowledge. Conversely, humanities-focused digital textbooks should emphasize aesthetic text layout, effective multimedia integration, and rich cultural representation to enhance learning experiences and cultural literacy.

IV. C. Strengthen resource guarantee and build a comprehensive support system

To drive high-quality development in digital textbook construction, the government should implement a series of supportive policies that actively engage universities, research institutions, and enterprises. Key measures include tax incentives and project funding to stimulate innovation across all stakeholders. For instance, establishing dedicated funds for digital textbook development could support research, production, promotion, and application processes. Priority funding should be allocated to projects with distinctive academic features and advanced technological content to accelerate innovation. Additionally, enhancing teacher training and technical support is crucial. Conducting digital textbook application workshops for educators—covering functional introductions, innovative teaching methods, and learning data analysis—will comprehensively improve teachers instructional capabilities. This enables educators to fully leverage digital textbooks advantages and enhance teaching quality. Furthermore, forming specialized technical support teams can provide timely solutions for technical issues encountered by both teachers and students. These teams could offer online support, phone consultations, and on-site assistance to ensure smooth implementationProvide services in various flexible ways such as guidance to ensure the smooth use of digital teaching materials.

IV. D. Improve evaluation feedback and improve the quality of digital teaching materials

Enhancing evaluation and feedback mechanisms embodies the user-centric philosophy in digital textbook development, which is crucial for establishing mature monetization models. Surveys indicate that leading international digital education publishers prioritize building robust assessment systems. For instance, Pearsons Revel design follows three core principles: reducing cognitive load, boosting engagement, and providing timely feedback. OpenStax, on the other hand, meticulously designs its products and services based on three key theories from Cognitive Science: "repeated retrieval practice", "spaced practice", and "feedback". To optimize evaluation mechanisms, practical measures include: First, developing a multi-dimensional assessment framework to ensure comprehensive and precise evaluations. This involves maintaining content accuracy, completeness, and relevance while ensuring technical compatibility, stability, and interactivity. Second, involving diverse evaluators such as subject matter experts, educational technologists, frontline teachers, and students to guarantee objectivity and fairness. Third, establishing efficient feedback channels through online surveys, suggestion boxes, forums, and social media platforms. Finally, creating. Establish a performance linkage mechanism, incorporate the evaluation results into the performance assessment of the development team, and reward teachers and students for their positive feedback and effective use [5].

IV. E. Promote interdisciplinary collaboration and stimulate collaborative innovation

The development of digital textbooks should transcend disciplinary boundaries and actively promote interdisciplinary collaboration. By pooling wisdom and resources from diverse fields, we can stimulate collaborative innovation to create more forward-looking, practical, and engaging digital educational materials. Specifically: First, encourage cross-disciplinary partnerships to integrate multiple strengths. Universities and research institutions should foster an environment conducive to

interdisciplinary cooperation through incentive policies that motivate experts and educational technologists from different fields to break down barriers and engage in deep collaboration for digital textbook development. Second, establish cross‑disciplinary teams to enhance coordination. To ensure efficient interdisciplinary collaboration, dedicated digital textbook R&D teams should be formed. These teams should include experts, educational technologists, and instructional designers from various disciplines, creating a diversified and comprehensive group. During team formation, emphasis should be placed on complementary expertise and collaborative communication, while cultivating interdisciplinary thinking and teamwork skills. Third, develop distinctive textbooks to drive quality upgrades. Through cross‑disciplinary collaboration and team innovation, we can jointly create digital educational materials that showcase disciplinary characteristics while maintaining high standards.

V. Conclusion

Amid the global digital transformation sweeping through education, the digitalization of higher education has become an irreversible trend. Developing digital textbooks for higher education requires differentiated strategies tailored to disciplinary characteristics, establishing discipline‑specific standards, enhancing resource allocation, improving evaluation mechanisms, elevating textbook quality, and fostering interdisciplinary collaboration to stimulate collaborative innovation. Looking ahead, with continuous advancements in information technology and ongoing educational reforms, high‑quality digital textbooks will better fulfill their role in cultivating moral character and nurturing talent within higher education.

Data sharing agreement

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

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