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Research on Circulation Mechanism of Digital Course Resources From the Perspective of Information Ecology Theory

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ABSTRACT

In this article, we discuss the stagnation problem related to circulating digital course resources (DCRs) in China. Using information ecology theory, questionnaires and practical tests, we learn that universities in China are embodied with information isolation, and hence circulating the associated DCRs is inhibited. Our results show that the original simple mechanical construction no longer meets the current needs of teaching and learning. Consequently, coordination is essential among relevant subjects and circulating DCRs. In doing so, we further reoptimise the current circulating system of DCRs in Chinese universities through the use of information ecology theory and in turn provide a new solution for the sustainable construction and application of DCRs.

KEYWORDS

Design Optimization, Digital Course Resources, Education Informatization, Information Ecology Theory, Information Isolation

1. INTRODUCTION

Digital technology is seamlessly integrated into our lives. It also applies to education. With the increasing availability of technology for teaching, digital technology not only provides new tools for education but also greatly changes teaching and learning (Cutajar, 2019; Gonza'lez, 2012). Especially during this severe COVID-19 pandemic, there has been an unprecedented global implementation of large-scale online education. Information technology has showcased its enormous potential to transform education, and it is irreversibly reshaping the ecological landscape of the education industry. As the provider of global educational reforms, China is actively participating in online courses. The Ministry of Education of China has successively issued a series of documents including the "Action Plan for Education Informatization 2.0", "China Education Modernization 2035", and "Implementation Opinions of the Ministry of Education on the Construction of First-Class Undergraduate Courses", requiring various universities to establish smart parks to provide a better network environment and platform for the implementation and development of education informatization, promote the construction of digital courses, strengthen the deep integration of information technology and

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curriculum teaching, and build many professional and high-quality digital courses (Han et al., 2018; Li, 2021). Based on the background of the new era, China's higher education informatization has moved from the 1.0 era to the 2.0 era, and from "simple application" to "deep integration". With the wide application of new-generation digital technologies such as artificial intelligence, 5G, and big data in the field of education, high-quality online education also plays a better role and function in serving the construction of the digital economy in the process of education digital transformation (Mao et al., 2022).

By the end of 2022, China had identified about 10,000 national first-class undergraduate courses. From 2019 to 2021, about 4,000 national online first-class courses (national quality online open courses), about 4,000 national offline first-class courses, about 6,000 national online and offline blended first-class courses, about 1,500 national virtual simulation experimental teaching first-class courses, and about 1,000 national social practice first-class courses have been identified.[1]Despite this, the construction of DCRs in China also faces severe challenges, especially regarding their circulation and application (Zhou, 2018). Through case studies and effectiveness analysis, we found that a serious phenomenon of information isolation is affecting the construction of DCRs in Chinese universities. Moreover, it makes course resources mostly stay at the display level rather than move to the actual application level, which markedly hinders the overall efficiency of China's educational informatization. Therefore, this article introduces the theory of information ecology to promote the circulation and application of DCRs in the teaching ecosystem. From this theoretical perspective, course resources are regarded as a kind of knowledge information, and the circulation system is identified as an information ecosystem composed of multiple information subjects. By stimulating and meeting the internal needs of each information subject, course resource circulation improves the circulation and application efficiency of course resources. According to this theoretical hypothesis, we design the ecological circulation mechanism of DCRs, which is composed of four basic circulation links (construction → identification → circulation → use) to explore a new path to realize the construction and sharing of DCRs.

2. CASE STUDIES AND EFFECTIVENESS ANALYSIS

The digital curriculum discussed in this article mainly refers to the collection of information that contains rich educational information and is published, stored, acquired, and utilized in digital form, which can support the design, preparation, implementation, and evaluation of courses, including course syllabus, teaching courseware, teaching design (teaching plan), teacher videos, practice questions, unit test questions, online homework, examination paper library, online discussion, teaching software, and teaching environment and other basic resources, as well as teaching reference books and extracurricular reading resources, which are learning-centered and teaching-guided curriculum resource integration, able to conduct teaching interaction and teaching evaluation with resources and activities. (Lai & Shi, 2021; Yu & Wang, 2022).

Taking Chongqing City as an example, during this severe COVID-19 pandemic, to ensure the online teaching resource demand of colleges and universities in the city, the open platform of Chongqing universities has more than 6,000 course resources at all levels and more than 750,000 professional teaching resource resources, making every effort to provide digital resource guarantee for colleges and universities to carry out online teaching. Free platform-level cloud space services are set up, and "MOOC+SPOC" online course teaching applications are supported in Chongqing universities. Since the outbreak of the COVID-19, Chongqing universities have relied on the platform to carry out online teaching, with a total of more than 600 new courses opened in a single month, and more than 250,000 new courses selected in a single month, mainly public general courses, professional basic courses, and professional theory courses. Figure 1 is a screenshot of the interface of the Chongqing Higher Education Smart Education Platform Course Resource Library, which reserves a wealth of high-quality course resources, that teachers can use to calmly conduct online interactive teaching,

Figure 1. Interface of the curriculum resource library of the Chongqing Higher Education Smart Education Platform

and the teaching quality is better than that of live online courses using other platforms such as OICQ, DingTalk, and Tencent Meeting.

According to publicly available data, the "University Alliance in Chongqing" has built a total of 171 national-level and provincial-level online courses, including 33 national-level and 138 provincial-level courses. The specific distribution is shown in Table 1.[2] Except for the Third Military Medical University, other universities have national-level quality courses. Chongqing University has 12 provincial-level excellent courses, ranking first among the seven regional universities, followed by Southwest University, while other universities have relatively few. It can be seen that the distribution of high-quality quality course resources in universities in Chongqing is uneven and inadequate.

The seven universities of the "University Alliance in Chongqing" have implemented credit recognition through the establishment of a "credit bank", and with the support of the high-education smart education platform, have effectively shared high-quality curriculum resources and improved the utilization rate of scarce high-quality curriculum resources. To understand the current status of digital course resource development, circulation, and utilization in universities, especially the current problems. We take Southwest University of Political Science and Law as an example, mainly using

Table 1. The situation of high-quality online course resources of "University Alliance in Chongqing" (as of December 2022)

Name of University	Number of National-Level Quality Courses	Number of Provincial Quality Courses	Total
Chongqing University	12	37	49
Southwest University	10	34	44
Third Military Medical University	0	14	14
Southwest University of Political Science and Law	5	22	27
Chongqing Medical University	3	18	21
Sichuan International Studies University	3	13	16
Total	33	138	171

Figure 2. Interface of the online course "Intellectual Property Law" of Southwest University of Political Science and Law

the questionnaire survey method to collect relevant data, and combining with relevant research and theoretical analysis, analyze the effectiveness of teachers and students of the school in using the higher education intelligence education platform to carry out teaching work during the COVID-19, and conduct a satisfaction survey on the smart online teaching system from the perspectives of teachers and students, to evaluate and test the effectiveness of the sharing action of higher education smart education platforms in the special period.

The Southwest University of Political Science and Law's digital course construction is organized on a course-by-course basis, with each course consisting of four modules: "announcements, course materials, assessments, and discussions."[3] Take the "Intellectual Property Law" course as an example, Figure 2 shows its online teaching course interface. In the testing system, students and teachers can conduct online discussions, download courseware, and participate in online assessments. Through the intelligent online teaching system, teachers can accurately grasp the learning effects of students. The system can also enable real-time interaction between teachers and students, as well as interaction between students at any point in the teaching process. It can also utilize the course communication and discussion area to further achieve personalized guidance. In addition, teachers can also assign homework and conduct classroom tests to students based on their learning interaction during online teaching.

To accurately grasp the effectiveness of online teaching during the COVID-19, Southwest University of Political Science and Law conducted comprehensive monitoring of online teaching in the whole university and implemented teaching supervision and listening to classes. We distributed an online questionnaire survey to 13,800 students in the school on the aspects of teacher management job satisfaction, teacher teaching clarity, platform teaching resource satisfaction, teacher teaching interaction satisfaction, online teaching satisfaction, and collected 12,000 questionnaires, the specific survey statistics are shown in Table 2.

Table 2. Statistics of online teaching survey of Southwest University of Political Science and Law during the COVID-19 (as of December 2022)

Teaching Number	Attendance Frequency	Teacher Online Attendance Rate	Student Online Attendance Rate	Online Satisfaction of Students	Homework Assignments	Exam Releases	Students With Special Circumstances
1	10	100%	99.2%	97.8%	16	6	6
2	14	100%	99.5%	89.0%	8	3	0
3	15	100%	99.0%	95.5%	12	0	7
4	10	100%	99.9%	97.0%	8	6	8
5	15	100%	98.0%	80.0%	8	8	10
6	1	100%	99.8%	98.4%	12	0	8
7	17	100%	97.8%	93.4%	20	8	5
8	4	100%	98.0%	86.8%	16	4	0
9	19	100%	99.5%	97.9%	12	8	10
10	15	100%	98.9%	96.0%	12	6	4
11	8	100%	99.7%	88.0%	15	0	10
12	7	100%	99.1%	97.0%	8	8	15
13	5	100%	99.2%	96.2%	8	0	0
14	59	100%	99.7%	98.3%	12	6	5
15	70	100%	99.9%	82.6%	12	6	5
16	22	100%	95.8%	96.5%	10	5	18
17	16	100%	99.9%	97.0%	16	8	14
18	40	100%	99.1%	94.0%	16	8	15
19	50	100%	99.7%	80.2%	15	8	10
20	31	100%	99.2%	75.5%	10	0	15
Total	428	100%	99.05%	91.86%	246	98	165

As can be seen from Table 2, the overall satisfaction of students with the effectiveness of digital courses is 91.86%, although there is still much room for improvement, such a large-scale online teaching action can achieve this satisfaction result. Among the 20 teaching units in the table, the student satisfaction rate of the 14th teaching unit is as high as 98.4%, but the student satisfaction of the 20th teaching unit is only 75.5%.

3. PROBLEMS AND ATTRIBUTION ANALYSIS

From the cases cited in the appeal, it can be seen that digital courses can not only solve the contradiction between the increasing demand for high-quality teaching resources in higher education and the insufficient and uneven distribution of these resources but also provide high-performance learning platforms and high-quality teaching resources for online learning for teachers and students during the pandemic. However, teaching practice is guided by communication and participation, DCRs as the constituent elements of teaching practice, also need to be put into practical application through circulation (Sfard, 1998). This is needed not only for teaching practice but also as a requirement

of the circulation attribute of course resources as a special commodity. Therefore, circulation and application issues play an important role in the construction of DCRs. Although universities have accumulated a large amount of digitalized curriculum resources, which have played a positive role in promoting the comprehensive development of education informatization. However, the construction of DCRs in China is facing severe challenges regarding circulation and application, which makes it difficult to translate the existing construction achievements into actual benefits. This problem can be explained from three dimensions: distribution of course resources, accessibility (openness) of course resources, and awareness and utilization rate of course resources.

Firstly, from the perspective of the distribution of curriculum resources, although there are a small number of national and provincial resource-sharing platforms, the sharing platforms that can provide DCRs are still in a decentralized state, and the course resources provided by each platform are facing other difficulties, such as an insufficient number of course resources and insufficient comprehensive course categories. Taking the Chongqing Higher Education Smart Education Platform as an example, whether it is the national quality courses or the teaching resource library, the content is the digitization of traditional paper-based textbooks, which does not reflect the characteristics of digitalization that can fully present images, videos, animations, sounds, and text in one. Even if there are video materials, they are only simple teacher lecture videos or simply teaching videos as digital teaching resources. The main reason for this problem is the single construction body. Many teachers in many quality courses are only nominally involved, without substantive participation. The single type of resources directly leads to the single structure, which also leads to the problems of repeated waste in the current teaching resource construction, the inability to achieve personalized construction based on actual teaching needs, and even more unable to meet the needs of students' personalized learning (Guo, 2014). In addition, due to the lack of organic connection between the information nodes between platforms, for example, the seven universities that can achieve credit mutual recognition and course sharing during the COVID-19 are limited to the seven universities of the "University Alliance in Chongqing" that can achieve credit recognition and course sharing during the COVID-19 pandemic, these will also lead to a state of self-enclosure between platforms, further limiting the realization of the goal of sharing course resources.

Secondly, from the perspective of the current results of offering quality curriculum resources, the degree of openness is low and access is difficult. We tested the resource stations of the seven universities of the "University Alliance in Chongqing" offering excellent courses to understand the accessibility (openness) of DCRs stations. The analysis of the test data reveals that as many as 71% of university course resource websites are unable to be accessed effectively, while only 29% of resource websites can be effectively accessed. Open access to resources has become a global consensus and a means to achieve efficient resource circulation and allocation. The diversity and vastness of digital resources have led to a wide array of course information being stored in cyberspace. However, truly high-quality DCRs are severely lacking, and there are very few effective pathways for teachers and students to access and share these resources (Zang, 2020). The sharing of DCRs fundamentally relies on the sharing of high-quality DCRs. The scarcity of high-quality resources fundamentally hinders the comprehensive and sustainable sharing of DCRs. Producing high-quality DCRs requires significant human and financial resources. In China, a substantial amount of high-quality DCRs are concentrated in well-established prestigious universities, such as the "University Alliance in Chongqing." These universities are often reluctant to share their educational resources, which have been acquired at a high cost, with the public for free. Moreover, the paid service-sharing model limits the number of users and the scope of access, further exacerbating the difficulty of obtaining high-quality DCRs. Additionally, the development of high-quality DCRs lacks standardized and specialized personnel training, leading to gaps in the development and construction of high-quality resources. This also hinders the continuous sharing and collaborative creation of high-quality resources.

Finally, the awareness and utilization rates of excellent courses are considerably low. We conducted a random questionnaire survey of some teachers and students from seven universities of

the "University Alliance in Chongqing" to understand their awareness and usage of quality course resources. The questionnaire survey was distributed randomly on campus, with a total of 1,000 questionnaires distributed and 850 collected, including 550 from teachers and 300 from students. The main purpose of the questionnaire survey was to gather information on teachers' and students' awareness of digital courses and to record their usage of digital courses. The results of the questionnaire survey show that as many as 76.21% of the students 'do not know' or 'have never heard of' excellent courses, and the proportion of teachers in this regard is 10.3%. For the use of quality courses, the proportion of teachers who know and use is 32.05%, while the proportion of students is relatively low, only 8.04%. The development and use of DCRs show different characteristics in different regions, and the awareness and utilization rate of DCRs also show great differences (Cai and Chen, 2019). Developed regions have strong economic, political, cultural, and other comprehensive strengths, but also occupy a large number of talents, educational resources, and hardware facilities, the research and development of DCRs are relatively rich, DCRs are systematic, standardized, wide-coverage, the awareness and utilization rate of DCRs is high. In underdeveloped areas, people still mainly rely on traditional teaching methods, the awareness of DCRs is not high, teachers have ideological limitations and one-sidedness, research interest is not high, the government and education departments lack financial support and equipment investment for the construction and development of DCRs, smart education platforms are more used for information release announcements, content updates lag, and students also lack the awareness of actively understanding and learning DCRs. In poor areas or rural areas with weak educational resources, there is a lack of basic teaching hardware facilities, a shortage of teachers, and few people who understand DCRs, let alone use them, which affects the overall sharing and co-construction of DCRs.

In short, through the above empirical data analysis, it can be shown that China attaches great importance to the construction of DCRs, actively participates in digital education reform, and has achieved relatively significant results in the number of courses. However, looking at the specific practical application of digital curriculum resources in different regions and at different levels of universities, there have been problems such as the fragmentation of curriculum resource platforms, low openness and difficulty in accessing quality courses, and unsatisfactory awareness and usage rates of quality courses. These problems have become major obstacles to the current construction of digital curriculum in China, and we urgently need to propose effective solutions to resolve them.

4. RESEARCH REVIEW AND THEORETICAL INTRODUCTION

In recent years, digital courses represented by micro-courses, MOOCs, cloud courses, and flipped classrooms have swept the country and become a "fashionable" form of education. In academia, many people believe that digital courses have "very broad educational application prospects" and "important practical significance", and are even considered to be the "development direction" of future courses. (Hu, 2011; Jia, 2016; Chen, 2019). However, while the construction of digital courses in China is booming, it inevitably faces various challenges and issues. Professor Li pointed out many paradoxes in the construction and sharing of course resources in the digital age (Li, 2015). Furthermore, Zhang Yanxin pointed out that these problems indicate that the current development of high-quality courses has entered a 'bottleneck' period, so it is necessary to turn to a dynamic construction (Zhang, 2017).

Regarding the problems with digital curriculum construction, some scholars have carried out further research, attempting to find the causes of and countermeasures for such problems. Wang Chongrun and others pointed out a technical reason that suggests the construction of DCRs is technically difficult and called for the strengthening of the technical guidance for the person in charge of course resources (Wang et al., 2010). Zhang Jianqiao believed that the root of the problem lies in the differences in understanding of information resource sharing among university administrators and suggested that university administrators should unify their understanding of resource sharing (Zhang, 2017). However, most studies analyze and suggest solving these problems from the technical

perspective of course resource construction while ignoring the systematic mechanism of course resource circulation and sharing. Therefore, it is not enough to explain and solve the problem of the circulation stagnation of course resources. Through analysis, we believe the fundamental reason for the circulation-application problem lies in the fact that the original simple mechanical construction ideas no longer meet the teaching needs in the digital era. Digital technology has led to fundamental changes in education, emphasizing the intersubjectivity, interaction, and sharing of teaching and learning (Pepin et al., 2017; Guerin et al., 2019). However, under the original construction, managers often focus on course resources, ignoring the relationship among subjects and between subjects and the environment, which transforms the course resources into scattered information isolations, thus becoming unable to meet teaching needs in the digital era (Li, 2016; Quan, Xiong & Xu, 2018). To address these issues, we suggest that the construction of course resources should move from considering original mechanical information theory to information ecology theory for better coordinating the relationship among multiple subjects and between subjects and the environment.

Information Ecology, this concept originated from the interdisciplinary research of information science, systems science, and ecology in the 60s of the 20th century, and gradually formed the theory of information ecology after decades of accumulation. In 1997, Thomas H. Davenport and Laurence Prusak first proposed the concept of "information ecology" from the perspective of information management in *Information Ecology: Mastering Information and Knowledge Environment*, pointing out that information ecology refers to the use of multiple cumbersome problems affecting the use of information within the organization to analyze the overall approach, and the use of a system view to analyze the problems that affect the interaction of many different situations (Davenpor & Prusak, 1997). In 1999, Nardi and O'Day discussed the information ecology at the cultural psychological level by defining the information ecosystem as "a system composed of people, practices, values, and technologies in a specific environment", emphasizing the importance of human information behavior in the information ecosystem (Nardi & O'Day 1999). In the process of theorizing information ecology, the focus has gradually shifted from discussing the ethical issues of information ecology to studying information ecosystems, and its core idea is to draw on the concept of natural ecology, regard information as a resource, and realize the rational use of information resources by regulating the information ecosystem composed of people and information environment (Yang & Yuan, 2022).

Compared with the mechanical information theory, information ecology theory explains how people know, create, publish and use information from the perspective of relationships (Wang,2013; Karen et al., 2007). With the progress of science and technology and the deepening of human attention to the self and society, the connotation and extension of information ecology theory have been continuously enriched and expanded and are widely used to explain various social and cultural activities of human beings, including e-commerce, social networks, knowledge services and supply chain management (Bekkers & Homburg, 2005; Malhotra, 2002; Huo et al., 2016; Shao, 2018). Based on this, we attempt to apply the theory of ecological information to research the circulation mechanism of DCRs, thus putting forward the concept of the DCRs circulation chain. Next, we will elaborate on the theoretical assumptions of the DCRs circulation chain from four aspects: constituent elements, functions, internal causes, and transmission mechanism.

4.1 The Main Elements of the DCRs Circulation Chain

According to the theory of information ecology, information ecology is primarily composed of interconnected elements such as information subjects, information resources, and information environments, and it possesses a certain degree of self-regulation capability.[4] In the information ecosystem, information subjects use a variety of information technology means to exchange information with the information environment, and finally stabilize the proportion, quantity, and flow of various types of information, thus forming an information ecological balance. According to the composition principle of the natural ecosystem energy flow model proposed by Eugene P. Odum, the information subjects are at the core of the system, in which the information producer, information transmitter,

and information consumer interact with other elements in the system through information exchange. Information content, information structure, information technology, and information equipment are all direct supporting elements of the information ecosystem. The outermost part of the system is the information culture and information system and laws, which stipulate or to a certain extent affect the information people's understanding of information awareness, information behavior, information technology, and the development and use of information equipment (Odum, 1997).

Firstly, information subjects mainly refer to all individuals or social organizations that need information and participate in information activities (Lou et al., 2014). In the information ecosystem, the information subjects are in the central position and grasp the trend of information flow, which determines the transmission of the information ecological chain and the effect of information activities. Information subjects are the only active element in the information ecosystem, it can be said that the information subjects play the greatest role in the information ecosystem, and any information ecosystem needs to be supported by the information subjects. Information subjects are divided into three categories according to their role in the information ecosystem: information producers (providers), information transmitters, and information consumers (users). An information producer is an individual or organization that manufactures and produces new information. Information transmitters include information organization and processing and information transmission, first classify information through simple labor (or provide information value-added services to users through complex innovative labor), and then transmit information to users, such as library and information units, information consulting institutions, science and technology information centers, et al. Information consumers refer to individuals or groups that receive and use information, such as management decision-making departments, researchers, and students (Kang et al., 2019). In the circulation system of DCRs in colleges and universities, the producers, transmitters, and consumers of course resources can be regarded as different types of information people, of which the producers of course resources are mainly college teachers, the transmitters are mainly composed of teachers, schools, governments, institutions, enterprises, and other subjects, and consumers are composed of students, teachers or individuals who use these course resources. In addition, curriculum resources are a collection of resources that link the constituent elements, which is the reason for the chain relationship between information people, and if it is separated from the curriculum resources themselves, then the "chain relationship" does not exist.

Secondly, the information resources mainly refer to the source of information, including digitized literature, books, pictures, audio, and video, et al. In the information environment, these resources are widely used and disseminated, providing essential information and knowledge for people's lives and work. Information resources are typically stored in various databases, network platforms, and data storage devices, managed and utilized through information technology and tools. The development and utilization of information resources is an important part of the information ecology. To better manage and utilize these resources, a series of measures and technical means need to be adopted, including data mining, data warehousing, and data visualization, to transform information resources into valuable information assets. At the same time, the quality of information resources needs to be evaluated and managed to ensure the accuracy and reliability of information (Yang & Yuan, 2022). Information in an information ecosystem is the glue between the information subject subsystem and the information environment subsystem. Through information, information subjects communicate with the information environment, transmit and maintain the balance of the information ecosystem. Information resources are the material support in the information ecosystem, without information resources, all information ecosystems are just empty talk (Zheng et al., 2021)

Thirdly, the information environment including the social environment and the technical environment, is a collection of two environments to which information subjects are attached when obtaining and sharing information resources (Zhang, 2009). The information environment in the narrow sense refers to information policy, information culture, information law, information ethics, et al. The information environment in the broad sense includes the basic supporting capabilities that will make

information or information subjects function, such as information technology, information structure and information content, and information equipment (Cai & Chen, 2019). How the information environment changes and develops affects the thinking and actions of information subjects, and at the same time plays a role in increasing or slowing down the activity cycle of information resources. In addition, the information environment can also provide relevant technical, economic, political, and cultural guarantees for the information activities of information subjects, and at the same time provide the necessary places for the acquisition and sharing of information resources.

4.2 The Main Function of the DCR Circulation Chain

The essence of information ecology is the mutual circulation of information resources between different types of information subjects through the information environment (Lou et al., 2014). Its functions mainly include resource acquisition and open sharing, resource exchange and personalized recommendation, learning feedback and update improvement, resource evaluation and quality control, sustainable development, et al. The digital course resource circulation chain has a variety of functions, which together constitute the important value and role of the digital course resource circulation chain, and promote the development and progress of digital education.

Therefore, the ultimate purpose of the information ecological chain is to improve the efficiency of information circulation, enhance the value of information, and meet the needs of the information subjects through value addition and proliferation of information. As valuable knowledge information, the circulation and dissemination of course resources will produce economic benefits and social values. When the communication scope is wider and the circulation efficiency is higher, the value-added range of course resources will be larger. Moreover, when consumers consume course resources to generate new knowledge or course resources, the course resources will achieve a new proliferation. Therefore, the function of the DCRs circulation chain is to promote value addition and proliferation of DCRs.

4.3 Internal Causes of the DCR Circulation Chain

The essence of the circulation of DCRs is that the information subjects carry out information activities around the production, transmission, and consumption of course resources. Therefore, the needs (motivation) of information subjects in the circulation of course resources are the key to answering the motivation of the course resource circulation chain, and it is also an important guarantee for stabilizing the chain relationship. By analyzing the internal motivation of three kinds of information subjects who participate in the information chain, we can find the following inherent motives of DCRs:

Firstly, the construction of digital curriculum resources not only meets the needs of producers but also stimulates their motivation to participate in curriculum construction. As the producer of digital curriculum resources, teachers have obvious utilitarian motivation to participate in this construction. In the construction of DCRs, it should be allowed to use the utilitarian motives of information providers. For example, teachers' participation in the construction of DCRs may provide them with opportunities conducive to professional development, such as title evaluation, completion of teaching and research tasks, and continuous learning and improvement of their professional knowledge by participating in the construction of DCRs, this intrinsic utilitarian motivation can motivate them to participate more actively in the construction of DCRs. Teachers are the key force in the construction of digital curriculum resources, and their active participation and investment are of great significance in promoting the informatization and intelligent development of education. The construction of digital curriculum resources can stimulate teachers' participation motivation through various internal and external factors, which is conducive to improving the quality and level of digital curriculum resources and promoting the innovation and development of education and teaching.

Secondly, although the transmitters of curriculum resources present a diverse state, universities, which are the beneficiaries and producers of information curriculum, are often the main force in the relationship between them. However, in the construction of the information ecological chain, due to the decentralization and closeness of universities and different emphases in teaching and research in

different universities, its power to promote the large-scale flow of courses is limited. Moreover, due to the lack of strength or weakening of incentives, it is difficult for other subjects, such as teachers, governments, and enterprises, to meet the different curriculum needs of multiple subjects. Because the existing transmitters cannot effectively collect, integrate, and transfer course resources, it is necessary to establish an organization responsible for the transfer of course resources through top-level design. This institution can serve as an "intermediary organization" similar to a publishing house, taking on the role and function of a course resource distributor, and promoting the circulation of digital course resources in universities through necessary operations.

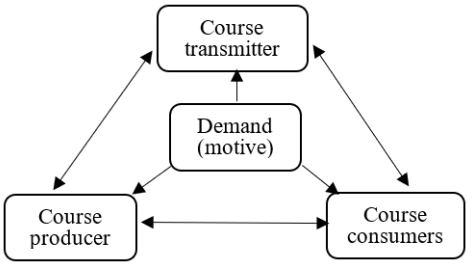
Thirdly, the course resource consumption behavior of the users (consumers) is determined by learning motivation. Due to the complexity of the social environment and education, the learning motivation of users is markedly diverse, which includes learners' internal learning needs (such as curiosity and the desire to explore), external incentives (such as high scores or grades and material or spiritual rewards), learners' cognition (such as attribution, expectation, self-efficacy, and goal orientation), will and emotional feelings (Fan & Zhang, 2007). The relevant research shows that although some people think that internal psychological needs (motivation) are also an important factor in driving learning, they cannot deny the influence of external utilitarian motivation on learning behavior. Moreover, according to several recent studies, external utilitarian demand, such as achievement, degree certificate, enrollment and employment, is the most significant learning motivation of current learners. Therefore, it is reasonable to believe that if we associate digital courses with these motivations, then the application of digital courses will be promoted.

In summary, social practice is a conscious action driven by needs. A good education mechanism needs to meet the needs of the society and individuals. Therefore, in the DCR circulation chain, the motivation of all parties to meet their own needs is the fundamental power of the circulation of DCRs and an important factor for the formation of the circulation chain of DCRs. In the whole process of digital course circulation, regardless of the producers, communicators, or consumers of the course, when what they obtain from work, learning, and play is directly proportional to the return (spiritual or material), under the function of a virtuous circle, more people will be encouraged to join the process of digital teaching and learning.

4.4 Transmission Mechanism of the DCR Circulation Chain

The mechanism is the interaction and relationship between elements. In the transfer process of DCRs, the ability of each information subject is limited. Therefore, in the context of the social division of labor, the producers, transmitters, and consumers of digital courses must find upstream and downstream in the relative division of labor and meet their survival and development needs through competition, cooperation, and exchange (Snyder et al., 2020). Therefore, the transmission mechanism of DCRs is the mutual relationship and function between information subjects. In the process of DCRs circulation, the market mechanism and capital operation principle play a fundamental role, in which the role of course resources is the demand of each subject as a special commodity regulator (Figure 3).

Figure 3. Circulation power and transmission mechanism of DCRs



Firstly, the ultimate mediator of all needs is the desire for consumption (Marshall, 1890). In terms of DCRs, the ultimate purpose of production for learners is to consume knowledge, which is the value of DCR production and circulation. According to the principle of capital operation, when DCRs are produced, if they can be spread timely and effectively for learners, then course resources can generate value addition and proliferation in circulation. Therefore, it is the most basic and effective transmission mechanism of DCR circulation to pull production through consumption demand, and it is also the most basic functional relationship between information subjects (An,2018)

Secondly, although consumption-driven production is the most basic transmission mechanism, the transmission mechanism of DCRs is multi-dimensional. Consumption drives production while production promotes consumption. Compared with traditional teaching, current digital learning is still in the edge position, so there is still much resistance to the process of promoting DCRs. However, if the digital course is better and easier to obtain than other learning resources available to learners and is related to learners' external utilitarian motivation, then the possibility of learners choosing DCRs for learning will increase to promote their circulation and application.

Thirdly, effective management and control are necessary to stimulate supply and demand and is another important transmission mechanism of course resource circulation. The management and control of DCRs transfer is undertaken by the course resource transferor, which is realized through the release and identification of courses. From the perspective of organizational form, the transferor of course resources is an intermediary between producers and consumers. We believe that the orientation of this institution should be an enterprise or institution with internet publishing qualifications under the supervision of the competent department of education, the main business of which includes the production, release and identification of digital courses. The organization can play a two-way role in promoting the flow of DCRs. On the one hand, the quality of course resources should be strictly controlled in the links of release and identification; on the other hand, reverse feedback should be used as a channel to hear the needs of students and absorb the advantages of hundreds of schools to lead the construction direction of course resources.

Finally, education is also closely related to national quality, comprehensive national strength and national competitiveness. Consequently, the circulation of digital courses also belongs to the public welfare entity. The investment of finance, policy, manpower, supervision and other aspects by the education administrative department is also an important factor in promoting and ensuring the operation of the entire DCR circulation chain. When the consumption demand is not enough to keep the education resource circulation chain operating effectively, the education administrative department should increase the consumption demand of course resources through financial subsidies, honor awards and other methods. For the market-oriented transferor of course resources, the education administrative department should ensure its safe, effective and smooth operation through capital investment, institution improvement and supervision. In addition, the education administrative department should also deepen the exploration of the excellent course evaluation mechanism to ensure more high-quality course resources participate in the DCRs circulation chain.

In summary, a digital course is a kind of information resource that relies on information technology for communication and storage. Its communication elements and structural relationship are similar to general information communication, and it has the basis for additional research with the help of information ecology theory. Therefore, based on the above theoretical basis, starting from the existing system and mechanism, through a comparison of the old and new mechanisms, this study explores and sets up more effective incentive and guarantee mechanisms to coordinate the relationship and function between the subjects of the course ecological chain to drive the rapid and effective circulation of course resources among course informants.

5. DESIGN CONCEPT AND MODEL CONSTRUCTION

From the perspective of system theory, the mechanism is a method to improve the overall efficiency of the system by promoting the coordinated operation of various elements within the system

through certain operational modes (Hedström and Ylikoski, 2010). Therefore, our design idea for the circulation mechanism of digital courses in universities is to closely focus on the main elements of the system to design corresponding mechanisms and strategies, fully tap into the driving force of digital course circulation, coordinate the relationship and role of the elements, and gradually move towards regularization and institutionalization.

Firstly, according to the main body demand of the digital course resource circulation chain, the information transmission mechanism (production, transmission, consumption) is decomposed into four links: construction, identification, circulation, use, and "demand-driven" runs through the entire circulation (Figure 4).

Secondly, by linking the substantive functions of the four links of construction, identification, circulation and use with the personal needs of circulation subjects, a guarantee mechanism with strong stability can be formed.

Thirdly, through the way of satisfying the needs of the subject (incentive mechanism) to form a driving force to stimulate the behavior of the subject, to promote the four links of construction, identification, circulation and use based on strong power, to drive the self-benign development of the circulation system.

5.1 The Circulation and Sharing of DCRs

The main construction of DCRs includes independent and cooperative construction (Figure 5). The platform for the collaborative construction of digital courses is a comprehensive information publishing platform: on one hand, all levels of education authorities, educational institutions, enterprises, and

Figure 4. Circulation mechanism of DCRs (overview)

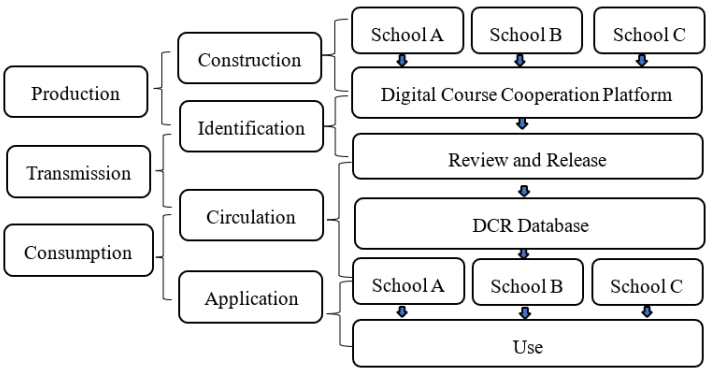
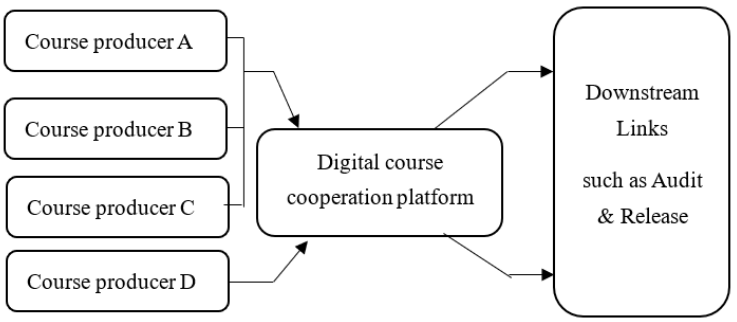


Figure 5. Construction of DCRs



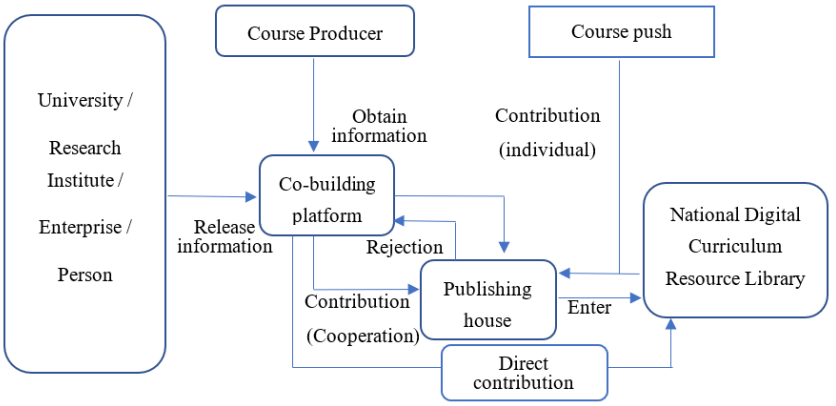
individuals can publish cooperation information on digital courses on this platform. On the other hand, each course producer can customize the personalized information-receiving service and cooperate according to their own needs, or according to their own production capacity and production conditions, through the collaborative co-construction platform to choose independent production or cooperative production to complete the course, the results of which are then through the corresponding audit and release mechanism to form a pooled way of curriculum resources, and then through the corresponding mechanism to share to users, to achieve the redistribution of curriculum resources.

It should be noted that the construction of a shared platform must adhere to the integrated service model inside and outside the school. A technical support team is set up by the academic affairs department on campus, and a technical service team is set up by platform providers outside the school to jointly be responsible for teaching informatization ability training and conducting special lectures. When building a platform, priority should be given to platform providers with high visibility, strong influence and excellent technical services, which should not only consider the provider's platform operation and maintenance guarantee capabilities but also take into account the provider's digital and electronic resource provision capabilities. In addition, through school-enterprise cooperation and joint construction of incentive mechanisms, high-quality curriculum resources are regularly evaluated and commended to further enhance the enthusiasm of teachers.

5.2 Release and Identification of DCRs

From the perspective of the content and quality of digital courses required for various types of education, the main body of DCRs still comes from colleges and universities themselves (including teachers and students). Therefore, the design of this article links curriculum construction with teacher title evaluation and teaching and research tasks and forms a linkage between universities, enterprises, and institutions through the design and construction of collaborative and co-construction platforms to achieve harmonious interaction in curriculum, technology, funding and other aspects (Figure 6). Through the electronic audio-visual publishing house to connect course builders and course users, ensure course quality and provide course consumers with positive release and identification as the strategy, and lead the construction direction of course resources through reverse feedback channels, to ensure the quality of course construction. The electronic audio-visual publishing house itself forms the corresponding influence of teaching resources through the course quality of the courses included, and creates a "course brand", to obtain corresponding benefits. On the one hand, digital course resource producers can choose to submit digital courses to electronic audio-visual publishing houses, or they can choose to submit courses directly to the national digital course resource database,

Figure 6. Release and identification of digital courses



and the national digital course resource database pushes courses to relevant electronic publishing houses according to the intention of course producers, and then the electronic publishing house reviews and evaluates the courses.

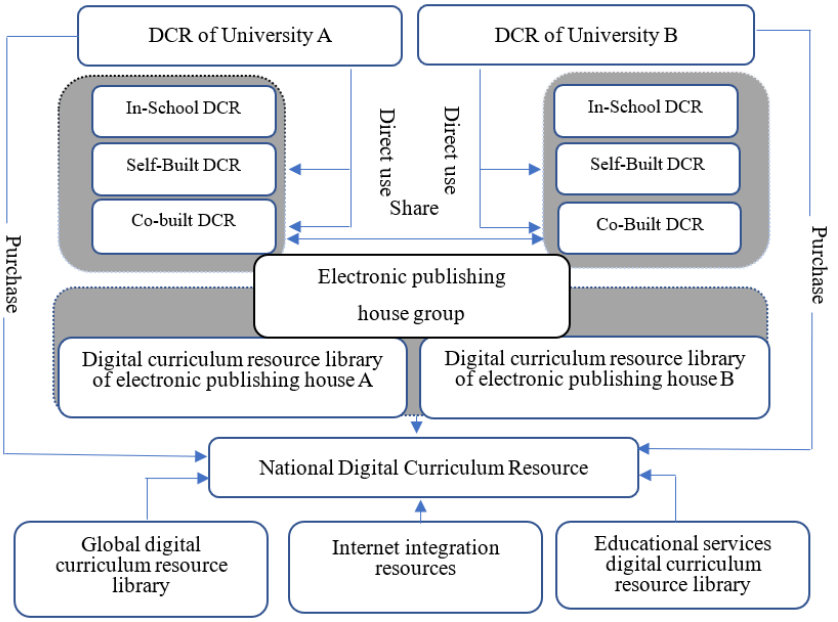
It should be noted that the sustainable development, sharing and co-construction of DCRs need to fully respect and protect the rights and interests of relevant stakeholders, and only when the rights of all parties are reasonably and legally guaranteed, cooperation is realized, and the community of interests is established, can the sharing and co-construction of DCRs be realized in essence. In the sharing and development of DCRs, universities, enterprises, institutions, individuals and other parties are involved. It is necessary to pay attention to the relationship and interest connection between each other, and when focusing on the degree of contact between stakeholders, it is an important way to achieve the sharing of DCRs by handling the interest factors and win-win conditions between the benefit sharing parties (Chen et al., 2022).

5.3 Establishment and Standardization of Sharing Mechanisms of DCRs

The circulation mechanism of DCRs is designed by referencing the CNKI (China National Knowledge Infrastructure) operation mechanism—the 'vertical paid use, horizontal free use' sharing mechanism. This mechanism answers the questions of how to share the resources built by universities alone or together and how to obtain other social resources (Figure 7). In the figure, Universities A and B can acquire only the self-built resources of each other by purchasing from the National Digital Curriculum Resource Library, while their co-built resources can be freely exchanged because they are created by both sides through cooperation. Due to the limited content and space of this study, the figure is not described in detail in terms of the technical and operational aspects. The figure is the main part of DCRs circulation, and the actual operation can be extended and refined based on this process.

In addition, the road to digitalized curriculum resource sharing not only requires the investment of various hardware devices and the allocation of personnel from all parties, but also requires the establishment of a sharing mechanism that encompasses the entire digitalized curriculum resource network platform through standardized management systems, incentive systems, evaluation systems,

Figure 7. Circulation and sharing of DCRs

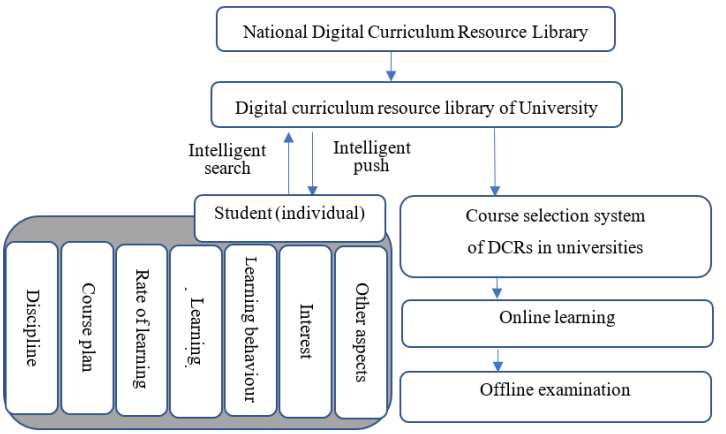


and other related systems, to create a personalized and harmonious operating environment for the sharing and co-construction of digitalized curriculum resources (Gao et al., 2020). Establishing a strict platform management system can standardize the use behavior of shared personnel, effectively clarify the responsibilities of platform staff, and implement a system management system that divides responsibilities into different levels and categories and assigns them to individuals. Establishing an effective incentive mechanism can stimulate the interest of resource owners in investing, continuously provide high-quality resources, set up financial incentives and special awards, and enhance the production motivation of scientific research institutions and platform vendors. An independent monitoring agency can be established to conduct regular inspections and supervision of the digital curriculum resource platform to ensure the implementation of the rights and responsibilities of stakeholders. Equipped with corresponding coordination agencies, specializing in handling conflicts and disputes among stakeholders, and sorting out the mutual interests. Set up a diversified evaluation system, focus on the evaluation criteria in the sharing process, regularly evaluate the curriculum resource projects, conduct statistics and surveys on the use of resources by teachers and students, and attach importance to the evaluation of the progress of resource sharing, overall results, and quality loopholes, to facilitate the sustainable development of the sharing mechanism (Zang, 2020). Only by establishing a complete set of digital course resource-sharing mechanisms can we effectively avoid risks and create a good social environment for digital course resource-sharing.

5.4 Use and Openness of the Sharing Platform of DCRs

In existing research, "use" is often included in "sharing", and the concepts of the two are often confused. But in fact, there is a qualitative difference between the two: "sharing" is a multi-agent behavior, while "using" only one subject (self or others), so "use" does not equal "sharing". By clarifying this point, this paper can better sort out the organizational structure and relationship of the circulation system, to better propose solutions. From the perspective of organizational structure, use is the downstream link of resource flow (sharing). On the one hand, DCRs are gathered into the national digital course resource database through a series of links such as construction, identification, and circulation, and then colleges and universities can purchase course resources in related fields according to their conditions, and intelligently open them to teachers and students through corresponding technical means. On the other hand, by strengthening the connection with academic education through the digital course credit system, stimulating and meeting the learning needs (motivation) of the majority of students in school, the overall circulation speed of DCRs can be quickly pulled. As can be seen from Figure 8, the National Digital Curriculum Resource Library brings together various teaching

Figure 8. Use of DCRs



courses at all levels in colleges and universities, digital course resource cloud libraries, and resource application service platforms. Universities can focus on the direction of running schools and the personalized learning needs of students, and carry out the construction of their curriculum resource library by purchasing course resources from the national digital curriculum resource database, to better support the current needs of blended learning.

In fact, as the main demander in digital courses, the status and needs of students are often neglected. In general, a significant feature of the current development of digital courses in China is that the focus on technology outweighs the focus on people. But "humans" should not stand in the shadow of technology. When it comes to truly high-quality technology, we need to consider how to better leverage human agency and initiative, and how to maximize the advantages of human beings. As Hutchins said when discussing educational technology, the goal is to help everyone fully develop their talents (Hutchins, 1969). Since the role of teachers cannot be replaced and the learning process of students is also essential, it may be a direction for us to consider the development of technology from a human perspective and explore what kind of digital curriculum should be provided based on human needs rather than the current status of technological development (Zhou, 2018).

6. CONCLUSION

In the field of education, information ecology theory can provide us with a new perspective, so that people can better understand and solve the problem of digital curriculum resource stagnation. By treating digital curriculum resources as a unique commodity in the education ecosystem, we can better plan and manage this important component for efficient use and sharing of resources. In this paper, we propose a series of measures and optimization designs, including the establishment of a national digital curriculum resource database, the implementation of the digital course credit system, the construction of a collaborative and co-construction platform, and the rethinking of the circulation mechanism of resources from the perspective of information ecology theory. Through these measures, the duplication and silos in the construction of DCRs can be effectively eliminated, and the efficiency and sharing of resources can be improved. This research is not only of great significance to the construction of college education informatization but also helps to improve the quality of education and promote educational equity. More importantly, it provides a new solution to solve the sustainable construction and application of curriculum resources.

It should be pointed out that the circulation mechanism of DCRs proposed in this article is a macro concept, which is a reorientation of the main role in the teaching ecosystem and a rethinking of the basic relationship according to the needs of teaching in the digital era. However, the perspective of this thinking problem also determines the horizon and result of thinking which indicates it is not feasible to conduct an in-depth study on the internal details of each circulation link. For example, the specific manner of interactions between universities may lead to difficulty in finding the best solution based on the actual situation. In addition, this article does not involve normative or standard issues in the circulation mechanism. For example, this article does not analyze the kind of action norms that each information subjects follow or the kind of recognition that standard course resources should use. These problems can be classified as technical problems of the circulation mechanism. Although they can be regarded as the blind area of information ecology theory, they do not affect the realization of the expected purpose of this article. However, to make the circulation mechanism of DCRs play a crucial role, it is necessary to solve the problems regarding matching the norms and standards with this mechanism.

DISCLOSURE STATEMENT

All the authors have no conflict of interest.

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ENDNOTES

1 Please see http://www.moe.gov.cn/jyb_xxgk/zdgk_sxml/sxml_gdjy/gdjy_jpgkk/
2 Please http://cq.gov.cn
3 Please see https://yjsy.swupl.edu.cn/
4 The constituent elements of the information ecosystem have several academic views such as the two-element theory, the three-element theory, and the four-element theory, and the difference mainly lies in the different understandings of the information environment, and the three-element theory and the four-element theory gradually subdivide the information environment in the broad sense of the two-element theory. Please see Lou 2014. Information ecosystem theory and its application. Beijing: China Social Sciences Press.