

Maturity Study of Digital Transformation of Teaching and Learning in Higher Education

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Abstract. The deep integration of higher education and digitalization in China is an inevitable trend. Assessing the effectiveness of digital transformation of teaching and learning in higher education through maturity evaluation is an important perspective. This study reviews the maturity research on digital transformation of teaching and learning at home and abroad. Based on the practical characteristics of higher education, it extracts the key elements of digital transformation and builds a measurement index system for digital transformation of teaching and learning in higher education. The system includes 3 basic dimensions, 9 key process domains, 26 sub key process domains, and 5 maturity levels. This study introduces a maturity index to better describe digital transformation in a more fine grained way.

Keywords: Digital transformation, Maturity assessment, Higher education.

1. Introduction

With the rapid development of digital technologies such as the Internet of Things, cloud computing, and artificial intelligence, education digitalization has become an important direction of global education reform. In recent years, China has attached great importance to the construction of education digitalization. China has held the 2024 World Digital Education Conference, built a global cooperation platform for digital education, and further promoted the digital education strategy action^[1].

Higher education is an important field of China's education digital transformation. After years of development, China has formed digital teaching platforms represented by the National Smart Education Platform for Higher Education, iCourse, and XuetangX. These platforms provide rich course resources and teaching services for universities and promote continuous innovation in teaching and learning models. As of January 2024, China MOOCs have launched more than 76,800 online courses, serving 1.277 billion users in China, offering 341 global integrated courses, and launching 10 global integrated certificate programs. China MOOCs also cooperate with more than 30 well-known universities and online education institutions worldwide to build a two-way communication channel for course import and export^[2].

With the continuous deepening of digital construction in higher education, digital transformation has gradually shifted from resource construction to quality improvement. How to scientifically evaluate the level of digital transformation of teaching and learning in higher education, identify shortcomings in construction, and continuously improve it has become an important issue in the development of higher education digitalization. In this context, the maturity model, as a value evaluation tool, is widely used in the education field and is also an important topic that many scholars continue to focus on.

This study focuses on higher education organizations and constructs a maturity model for digital transformation of teaching and learning in higher education. This study assigns weights to each indicator and introduces a maturity index. This study conducts a quantitative evaluation of the level of digital construction in teaching and learning in higher education and measures its development changes over time. This study provides a reference for the evaluation of digital transformation of teaching and learning in higher education.

2. Literature Review on Digital Transformation Maturity Research

2.1. Maturity Model

The concept of maturity originates from natural ecosystems and is used to describe the state of gradual development from the early stage to the mature stage^[3]. Nowadays, maturity is widely applied in various fields and usually refers to the state in which an object reaches a high level of development or is ready for use^[4]. Carnegie Mellon University Software Engineering Institute defines maturity as a comprehensive description and measurement of the development level of an object. It emphasizes continuous improvement through definition, management, measurement, and control^[5].

Scholars generally measure the maturity of development by constructing maturity models. Maturity models can identify the gap between the current state and the target state of an organization and provide a basis for optimization decisions^[6-7]. The maturity model was first developed from the Capability Maturity Model (CMM) proposed by the Software Engineering Institute at Carnegie Mellon University. The model divides maturity into five levels: initial level, repeatable level, defined level, managed level, and optimizing level^[8].

In recent years, maturity models have been widely applied in digital transformation research. These studies mainly focus on general frameworks for enterprises and specific industries, such as manufacturing, information services, and public management. In the field of education, Professor Marshall first proposed the e-Learning maturity model and designed a relatively complete evaluation process and indicator system, which became an important milestone in the research on digital transformation maturity in education^[8].

2.2. Maturity Models for Digital Transformation of Teaching and Learning

Compared with the enterprise field, research on digital transformation maturity in the education field is relatively limited, especially in China where it started relatively late. In recent years, foreign research has gradually shifted from general frameworks to regional models or higher education focused models, while domestic research mainly focuses on general models. Existing studies generally adopt a bottom up construction method, which first determines 3 to 6 evaluation dimensions and then divides maturity levels^[9]. Among them, the five level maturity classification is the most common.

A review of existing studies shows that maturity models for digital transformation of teaching and learning can be divided into three types: macro models, partially micro models, and micro models. Macro models are the most common and usually cover multiple aspects such as environment, facilities, and resources. They are used to evaluate the overall level of organizational digital transformation^{[7][10][11-14]}. Partially micro models further refine key areas based on macro frameworks, such as teaching, research, or services. A small number of studies adopt a micro perspective and directly focus on specific business processes and educational practice activities^[15-16].

Dimensions and key process domains are the most important parts of constructing maturity models. Based on a review of existing studies, the core dimensions of education digital transformation maturity models can be summarized into the following five categories.

2.2.1. Strategic Planning

Strategic planning is one of the most important key process domains. It provides leadership and practical guidance for the digital transformation of educational organizations. Existing studies generally emphasize that educational organizations should build a systematic strategic system by clarifying digital visions, goals, and implementation paths to ensure resource allocation efficiency and transformation coordination^{[10-14][17-18]}. Some scholars further emphasize the importance of leadership and point out that national policy support, organizational leadership ability, and incentive mechanisms all affect the effectiveness of strategic implementation^{[3][13]}.

2.2.2. Infrastructure

Infrastructure is the physical and technical foundation supporting education digital transformation. It mainly includes information systems, network environments, and digital resources. Scholars generally agree that system platforms are the core carriers and provide basic services for teaching, management, and evaluation. At the same time, information security and network construction ensure data security and stable operation of systems. They are the most basic infrastructure for building the space of digital transformation^{[3][11][12][15][16][18]}. In addition, some scholars focus on technical resources^[15-16] and educational digital resources^{[3][10-11]}. A few scholars emphasize the integration of the smart campus ecosystem^[11-12] or infrastructure monitoring and regular review^[18].

2.2.3. Organizational Ecosystem

The organizational ecosystem dimension focuses on the organizational structure, culture, and governance mechanisms of educational organizations. It is an important internal support for digital transformation. Existing studies generally believe that educational organizations should build learning organizations and collaborative mechanisms to improve their ability to adapt to digital transformation^{[3][11][14]}. At the same time, the attitudes and practical abilities of organizational members toward digital transformation are considered important factors driving transformation^[12-13]. A few studies also point out that internal educational organizations should collaborate with external entities such as governments and enterprises to maximize the value of digital transformation^[10].

2.2.4. Data Governance

Data governance is a key dimension that has received increasing attention in recent years. Its core is to improve data quality and data utilization efficiency through data standards and regulations. Educational organizations should establish a unified standard system covering data collection, storage, sharing, and application to support educational decision making^{[10][12][14]}. At the same time, with the expansion of data scale, it is necessary to establish educational government information big data and improve data management and analysis capabilities to release the value of data^[12].

2.2.5. Development Performance

Development performance is used to measure the final outcomes of digital transformation and is an important result dimension of maturity models. Related studies mainly discuss development performance from both macro and micro perspectives. At the macro level, they emphasize the impact of digital transformation on school development and teacher and student literacy, with the ultimate goal of promoting social development and improving social satisfaction^[11-12]. At the micro level, they focus on the changes in teachers' and students' digital abilities and learning methods^{[3][10][13][15-17]}.

In summary, existing maturity models for education digital transformation have formed a five dimensional structure with strategic planning, infrastructure, organizational ecosystem, data governance, and development performance as the core dimensions. However, these models are still mainly general macro models and lack refined models for higher education contexts^[19]. At the same time, most studies remain at the stage of theoretical construction and lack unified quantitative methods and empirical validation. Therefore, the explanatory power and practical applicability of these models in real applications still need to be improved.

3. Construction of the Maturity Model for Digital Transformation of Teaching and Learning in Higher Education

The maturity model for digital transformation of teaching and learning describes the dynamic evolution process of digital construction in educational organizations. It is a stepwise framework that systematically evaluates the entire process of teaching and learning. Generally, a maturity model consists of two parts: a structured evaluation framework and maturity levels. The evaluation framework includes key dimensions, key process domains, and key practices. The maturity levels describe the evolution stages of an organization from low to high.

3.1. Key Process Domains of Maturity

This study refers to the maturity evaluation frameworks proposed by Chinese scholars, weakens the influence of policy orientation, and combines the characteristics of higher education, including digital teaching models and digital education, to construct an evaluation framework that emphasizes the integration of teaching and learning practices. Finally, this study forms an evaluation system based on the dimension of strength, which consists of 3 basic dimensions, 9 key process domains, and 26 sub key process domains. Each indicator is coded accordingly. The maturity evaluation framework for digital transformation of teaching and learning in higher education in China is shown in Table 1.

Table 1. Maturity Evaluation Framework for Digital Transformation of Teaching and Learning in Higher Education in China

Dimension	Key Process Domain	Sub Key Process Domain
Digital Support Capability	Strategic Planning (A)	Mission and Vision (A1)
		Positioning and Goals (A2)
		Institutional Measures (A3)
	Infrastructure (B)	Information Network Infrastructure (B1)
		Information Security Infrastructure (B2)
		System Platform Infrastructure (B3)
		Smart Campus Infrastructure (B4)
	Teacher and Student Digital Intelligence Literacy (C)	Digital Awareness (C1)
		Digital Technology Knowledge and Skills (C2)
		Digital Application and Innovation (C3)
Digital Execution Capability	Organization and Ecosystem (D)	Organizational Structure (D1)
		Organizational Culture (D2)
		Evaluation Mechanism (D3)
	Data Governance (E)	Data Standards (E1)
		Capability Building (E2)
		Data Sharing (E3)
	Digital Teaching (F)	Digital Teaching Environment (F1)
		Digital Teaching Resources (F2)
		Digital Teaching Models (F3)
		Digital Learning (F4)
Digital Contribution Capability	Digital Teaching Management (G)	Digital Teaching Management (G1)
		Digital Teaching Evaluation (G2)
	Digital Support and Services (H)	Digital Services (H1)
		Digital Education (H2)
		Digital Benefits (I1)
		Digital Efficiency (I2)

3.1.1. Digital Support Capability

Digital Support Capability refers to the basic supporting capability of universities during the digital transformation of teaching and learning. It covers the improvement of hardware facilities and software capabilities, and mainly includes five key process domains: strategic planning, infrastructure, teacher and student digital intelligence literacy, organizational ecosystem, and data governance.

(1) Strategic Planning. This dimension emphasizes the top level design capability of universities in digital transformation. It mainly includes mission and vision, positioning and goals, and institutional measures. It clarifies the overall direction, development stages, and implementation paths of digital transformation, and ensures the implementation of strategies through institutional systems.

(2) Infrastructure. This dimension is the physical and technical foundation of digital transformation. It includes information networks, information security, system platforms, and smart campus construction. It mainly supports the digital operation and system integration of teaching and management and promotes the sustainable development of universities.

(3) Teacher and Student Digital Intelligence Literacy. This dimension emphasizes that teachers and students should have good digital values and the ability to use digital devices. They should combine digital creativity with data thinking to spread knowledge and solve problems, forming dual literacy of digital and intelligence. It mainly includes digital awareness, digital technology knowledge and skills, and digital application and innovation capability. It is an internal driving force for digital transformation.

(4) Organizational Ecosystem. This dimension focuses on internal governance and internal and external collaboration mechanisms in universities. It includes organizational structure optimization,

digital culture construction, and evaluation mechanism improvement, enabling organizations to adapt to the needs of the digital era and achieve efficient execution capability.

(5) Data Governance. This dimension emphasizes the standardized management and value utilization of educational data. It includes data standards, capability building, and data sharing, aiming to improve the quality and efficiency of teaching and learning and avoid data island problems.

3.1.2. Digital Execution Capability

Digital Execution Capability refers to the ability of universities to integrate digital basic capabilities into the entire process of teaching and learning and daily operations. It covers teaching, management, support, and services, and mainly includes three key process domains: digital teaching, digital teaching management, and digital support and services.

(1) Digital Teaching. It refers to the integration of digital technologies into the basic teaching process of universities. It mainly includes digital teaching environment, digital teaching resources, digital teaching models, and digital learning. By building digital teaching spaces and integrating online courses and multimedia resources, it promotes innovation in teachers' teaching methods and improves students' independent learning ability.

(2) Digital Teaching Management. It refers to the use of digital technologies to optimize teaching management and evaluation systems, including digital teaching process management and digital teaching evaluation. It improves management efficiency through digital methods and builds a comprehensive two way teaching evaluation mechanism between teachers and students.

(3) Digital Support and Services. It refers to the application of digital technologies beyond teaching, including digital services and digital education. It optimizes administrative and daily service processes for teachers and students through digital technologies and integrates Party and Youth League building and ideological and political education into digital platforms.

3.1.3. Digital Contribution Capability

Digital Contribution Capability refers to the benefits brought by digital construction in universities. It is measured by digital performance and includes two aspects: digital benefits and digital efficiency.

Digital benefits are reflected in teachers and students achieving better teaching and learning outcomes in a digital environment, which provides positive support for future development. Digital efficiency refers to achieving higher teaching and management efficiency with lower resource input by optimizing business processes through digital technologies.

3.2. Maturity Levels

Chinese scholars generally divide the maturity of education digital transformation into five levels [12][18][19]. Based on this, this study divides the evolution process of digital transformation into initial level, growth level, improvement level, optimization level, and maturity level by considering the characteristics of higher education.

3.2.1. Initial Level

Level 1, Initial Level, represents the starting and disordered stage of digital transformation in universities. The overall digital awareness is relatively weak, and a systematic strategy and planning have not yet been formed. Infrastructure and digital resources are insufficient, and information system construction is inadequate. Teaching and management still mainly rely on traditional methods. Teachers and students mainly depend on offline teaching and manual management processes. Data collection and processing methods are extensive, lacking unified standards and governance mechanisms. The overall scope of digital application is limited, and an effective digital teaching and management ecosystem has not yet been formed.

3.2.2. Growth Level

Level 2, Growth Level, represents the exploration stage of digital transformation in universities, with a focus on promoting infrastructure construction. Universities initially clarify the direction of digital strategy, but the implementation paths are still unclear. Infrastructure such as information

networks and system platforms is gradually improved, but the depth of technology application is limited. Teachers' and students' digital literacy improves, but it mainly focuses on basic applications. Digital centers and management mechanisms are initially established. Teaching management begins to adopt digital methods, but data governance capability remains weak, with problems of data dispersion and low efficiency.

3.2.3. Improvement Level

Level 3, Improvement Level, represents the relatively improved stage of digital transformation in universities, with a focus on the integration of digital technologies with teaching and learning and the expansion of digital services. University strategic planning and institutional systems are gradually improved. Infrastructure and information systems are relatively complete and initially achieve integration, but security capabilities still need to be strengthened. Digital applications expand from teaching to management and services. Teachers' and students' application levels improve, but innovation remains insufficient. Data governance is gradually standardized, but data utilization capability is limited. An initial digital ecosystem is formed overall.

3.2.4. Optimization Level

Level 4, Optimization Level, represents the stage of deep integration in digital transformation of universities. Digital technologies are fully integrated into teaching and management processes. Teachers and students can skillfully use digital tools for teaching and learning. Blended learning and flipped classrooms are widely applied, and digital intelligence literacy is significantly improved. Universities establish a comprehensive evaluation system and achieve data driven management, improving resource allocation and operational efficiency. They also have strong data analysis capabilities, but cross system data sharing is insufficient, and data island problems still exist.

3.2.5. Maturity Level

Level 5, Maturity Level, represents the mature innovation stage of digital transformation in universities. Infrastructure and data systems are highly developed. Data integration and sharing are achieved, supporting multi business collaboration. Digital technologies are fully integrated into the entire process of teaching and education. They significantly improve education quality and efficiency, form a stable and efficient digital ecosystem, and play a leading and exemplary role in education reform.

3.2.6. Principles of Maturity Level Classification

Based on the description of maturity levels, this study assigns sub key process domains to the corresponding levels. The Initial Level does not contain any key process domains, while the Growth Level to Maturity Level all have related indicators. This forms an evaluation model with hierarchy, dynamics, and a three dimensional structure to reflect the gradual evolution process of digital transformation in universities. The specific classification is shown in Table 2.

Table 2. Maturity Level Classification of Digital Transformation of Teaching and Learning in Higher Education

Maturity Level	A	B	C	D	E	F	G	H	I
Level 1									
Initial Level				No Key Process Domain					
Level 2	(A1)	(B1)	(C1)	(D1)		(F1)	(G1)		
Growth Level	(A2)	(B3)	(C2)			(F2)			
Level 3	(A3)	(B4)		(D2)	(E1)			(H1)	
Improvement Level									
Level 4			(C3)	(D3)	(E2)	(F3)	(G2)		(I2)
Optimization Level						(F4)			
Level 5									
Maturity Level		(B2)			(E3)			(H2)	(I1)

When using the maturity model for evaluation, a key process domain is considered achieved when its score reaches 60% or above of the full score. A score between 60% and 85% indicates basic

achievement, while a score between 86% and 100% indicates complete achievement ^[11]. If an organization completes all key practices within a key process domain, the key process domain is considered achieved. If an organization completes all key process domains of a maturity level and the levels below it, the organization is considered to reach that maturity level ^[20]. The improvement of maturity levels in universities requires meeting all process domains of lower levels first and then gradually satisfying the requirements of higher levels. This classification method can describe the gradual evolution process of digital transformation in universities and can be used for self evaluation and improvement.

3.3. Application Process of the Maturity Model

When using the maturity model for evaluation, the defined key process domains and their key practices need to be transformed into corresponding measurement items. A structured evaluation questionnaire is then formed using the Likert scale ^[11]. This study constructs a quantifiable indicator system, uses the Analytic Hierarchy Process to assign weights, and calculates the maturity index to achieve dynamic measurement and evaluation of the level of digital transformation in universities.

3.3.1. Measurement Items

Taking teacher and student digital intelligence literacy (C) as an example, the measurable items are shown in Table 3.

Table 3. Measurement Items of Teacher and Student Digital Intelligence Literacy (C)

Sub Key Process Domain	Measurement Item	Option
Digital Awareness (C1)	Teachers are willing to actively integrate digital tools/resources into teaching and research activities.	A. Strongly Disagree B. Disagree C. Neither Agree nor Disagree D. Agree E. Strongly Agree
	Teachers first seek help through digital platforms when they encounter problems in teaching and research activities.	
	Teachers believe that using digital tools/resources can improve their teaching effectiveness.	
	Students are willing to use digital tools/resources to assist their learning process.	
	Students first seek help through digital platforms when they encounter problems during learning.	
	Students believe that using digital tools/resources can improve their learning effectiveness.	
Digital Technology Knowledge and Skills (C2)	Teachers frequently use artificial intelligence software tools.	A. Strongly Disagree B. Disagree C. Neither Agree nor Disagree D. Agree E. Strongly Agree
	Teachers master the software operation skills required for teaching and research activities.	
	Teachers master the software operation skills required for daily life.	
	Students frequently use artificial intelligence software tools.	
	Students master the software operation skills required for learning.	
	Students master the software operation skills required for daily life.	
Digital Application and Innovation (C3)	Teachers can solve problems in teaching and research activities or work through the use of digital tools/resources.	A. Strongly Disagree B. Disagree C. Neither Agree nor Disagree D. Agree E. Strongly Agree
	Teachers can use digital tools/resources to explore new teaching models and methods during teaching and research activities, such as flipped classrooms and online collaboration.	
	Students can solve problems in learning and daily life through the use of digital tools/resources.	
	Students can use digital tools/resources for independent and exploratory learning during the learning process.	

3.3.2. Indicator Weights

This study invites 6 experts and uses the Analytic Hierarchy Process (AHP) to calculate the indicator weights of the maturity model for digital transformation of teaching and learning in higher education. The comprehensive weights of all indicators are shown in Table 4.

Table 4. Comprehensive Weights of Key Process Domain Indicators

Dimension	Key Process Domain	Sub Key Process Domain
Digital Support Capability 0.5284	(A) 0.1542	(A1) 0.0694
		(A2) 0.0488
		(A3) 0.036
		(B1) 0.0391
	(B) 0.0936	(B2) 0.0238
		(B3) 0.0203
		(B4) 0.0104
		(C1) 0.0273
	(C) 0.1019	(C2) 0.0431
		(C3) 0.0315
Digital Execution Capability 0.3316	(D) 0.1094	(D1) 0.0369
		(D2) 0.0355
		(D3) 0.0369
		(E1) 0.0302
	(E) 0.0693	(E2) 0.0217
		(E3) 0.0174
		(F1) 0.0648
		(F2) 0.0549
	(F) 0.1876	(F3) 0.0413
		(F4) 0.0266
Digital Contribution Capability 0.14	(G) 0.0966	(G1) 0.0682
		(G2) 0.0284
	(H) 0.0474	(H1) 0.0241
		(H2) 0.0233
	(I) 0.14	(I1) 0.0855
		(I2) 0.0545

Overall, experts believe that higher education should pay more attention to digital support capability during the digital transformation of teaching and learning. Digital support capability accounts for 52.84% of the total weight, while digital contribution capability is relatively less important. Among the key process domains, digital teaching has the highest weight of 18.76%. Among the sub key process domains, digital benefits are the most important.

3.3.3. Maturity Index

This study introduces the concept of the maturity index to quantify the maturity score of digital transformation of teaching and learning in universities. Compared with the macro judgment that only relies on maturity level classification, the maturity index can reflect dynamic improvement within the same level. Universities can compare changes in the index through multiple evaluations to examine the digital transformation process of teaching and learning at a micro level. The maturity index is calculated as the product of the score of each sub key process domain and its comprehensive weight. The calculation formula is as follows:

$$Z = \sum_{i=1}^n n_i * \omega_i, \quad i = 1, 2, \dots, n$$

Where Z represents the maturity index, and i , n_i , and ω_i represent the sequence number, score, and comprehensive weight of each sub key process domain, respectively.

4. Conclusion

The maturity model constructed in this study provides a reference for the evaluation and practice of digital transformation in higher education. However, it still has some limitations. The indicator system is mainly based on literature review, which involves some subjectivity and needs further

improvement. Future research will improve the maturity model and indicator system, introduce expert evaluation to enhance scientificity and applicability, and conduct multiple longitudinal evaluations in practice. It will continuously track the digital transformation process of universities to more comprehensively describe the micro evolution path of universities.

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