Research on the construction of digital resilient campus under the background of new education infrastructure

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Abstract. Based on the background of the national education new infrastructure strategy, this study proposes the concept of "digital resilient campus" to address the problems of network interruption, data governance failure, and teaching service obstruction in universities during emergencies, and constructs a measurement scale covering three dimensions: network infrastructure, data governance, and teaching services. The study formed 30 initial items, and after reliability, validity, and discrimination tests, the final scale showed good internal consistency, stability, content and structural validity, and significant discrimination. The validation of predictive validity further proves that scale scores can effectively predict the response capability of campus system failures. The research conclusion indicates that this scale can serve as an evaluation tool for the digital resilience level of universities, as well as provide quantitative basis for planning new infrastructure investment, improving governance mechanisms, and optimizing teaching services. It has important practical significance for promoting the stable operation of the education system.

Keywords. new infrastructure for education, digital resilience, digital campus, information security

1.Introduction

Under the framework of China's "new infrastructure" strategy, the education sector is undergoing a profound transformation centered on digitization [1]. The new infrastructure for education covers multiple elements such as 5G networks and gigabit fiber optic campus networks, large-scale computing nodes, education big data centers, artificial intelligence and blockchain technology application platforms, and integrated terminals for IoT perception and teaching. This system aims to break through the "network bottleneck" and "computing power weakness" of traditional campuses, achieve efficient allocation of educational resources, and provide solid support for new educational models such as personalized teaching [2]. At the policy level, a series of documents such as the "14th Five Year Plan for the Development of Digital Education" and the "Action Plan for Education Informatization 2.0" have been successively issued, providing guidance for the promotion of new education infrastructure and demonstrating the strategic intention of the country to reshape the education ecology and improve the quality of education through high-tech.

However, as the new infrastructure structure of education becomes increasingly perfect, multidimensional risks such as sudden public health emergencies, natural disasters, cyber attacks, and system failures occur frequently, seriously challenging the stability of teaching and research activities [3]. The concept of digital resilience emerged as a result [4]. Digital Resilience refers to the ability of information systems to achieve functional integrity through a closed-loop operation of four stages: perception response recovery evolution, in the face of external shocks or internal failures [5]. Resilient Campus is a system engineering paradigm proposed based on the concept of digital resilience, targeting the special needs of the education field [6]. It emphasizes the construction of four architectural units, namely "multi-level network topology+cloud and edge collaborative computing power+secure and trustworthy identity and data management+intelligent operation and maintenance decision support", to achieve full dimensional elastic collaboration from physical space, namely campus network and terminals, logical space, namely applications and platforms, to organizational space, namely governance and collaboration [7]. As a result, Resilient Campus goes beyond the narrow scope of traditional "disaster recovery backup" and integrates "elastic carrying fast switching intelligent optimization" into the entire education process, building a high-quality and sustainable education ecosystem for future complex environments [8].

In the current field of digital resilience campus research, although scholars have approached from different perspectives, there are structural shortcomings that prevent the provision of truly actionable improvement paths for practice [9]. At the conceptual level, most research on "digital resilience" and "resilient campus" only stays at a macro level, lacking a detailed analysis of the internal logical relationship between the two [4]. Scholars often simply equate the two, or only view digital resilience as the technological support for resilient campuses, while ignoring the dynamic coupling mechanism between the two in the "perception response recovery evolution" cycle [6]. Such coarse-grained conceptual frameworks are difficult to guide subsequent model design, making it difficult for research to go beyond the level of conceptual advocacy. At the theoretical modeling level, existing research mainly relies on the resilience theory of information systems, with less emphasis on the organic integration of social technological systems and organizational adaptation theory. The single theoretical perspective has resulted in the fragmentation of analytical dimensions. Some focus on backup of technical architecture, while others emphasize emergency response processes, but pay less attention to the significant shaping effect of organizational culture, decision-making collaboration, and stakeholder interaction on digital resilience [10]. As a result, the construction path lacks a comprehensive perspective, making it difficult to reflect the collaborative feedback process of multiple subjects in different sudden situations. At the level of evaluation methods, most studies tend to use qualitative interviews or questionnaire surveys, supplemented by case analysis, to form empirical conclusions [4]. However, these studies often lack systematic quantitative evaluation tools - there is no unified indicator system or scientific calculation method for indicator weights, and the reproducibility of evaluation results is insufficient. In addition, few studies have delved into the coupling logic between evaluation results and improvement strategies, making it difficult to transform evaluation work into actionable improvement plans.

There are obvious shortcomings in existing research, and it is urgent to establish a systematic evaluation framework that takes into account multiple subjects and dimensions, and has operability and generalizability. Based on this, this study constructs a comprehensive evaluation model for campus digital resilience on the basis of the "Antidipate Monitor Respond Learn" resilience engineering framework [11], refines the dynamic interaction mechanism of perception response recovery evolution to achieve the scientificity of quantitative evaluation, and through multi school empirical and hierarchical strategy verification, forms a "start development upgrade" closed-loop path from evaluation to improvement, providing operational decision support for higher education institutions to build a high resilience information ecology under the background of education new infrastructure, and providing theoretical and practical paradigms for the implementation of national education new infrastructure policies.

2. Theoretical analysis

Digital resilience requires not only the anti-interference ability of underlying infrastructure, but also the construction of monitoring capabilities, response capabilities, and learning and evolution capabilities based on post event analysis. The authoritative Resilience Engineering theoretical framework includes the four elements of "Antidipate, Monitor, Respond, Learn", providing systematic guidance for the connotation and technical path of digital resilience. Its core lies in upgrading passive recovery to active evolution, expanding a single recovery mechanism into a continuous improvement loop, and empowering information systems with the self reconstruction characteristic of "resilience" rather than "rupture" [11].

This study is based on the theory of Socio Technical Systems (STS) and combines the resilience generation mechanism of Complex Adaptive Systems (CAS) to construct a digital resilience campus evaluation system under the background of new educational infrastructure [12, 13]. The STS theory emphasizes the collaborative evolution relationship between the technical subsystem and the social subsystem, which provides a multidimensional collaborative analysis framework for this study. In the context of digital campus, technological elements such as infrastructure and data resources must form a mutually empowering symbiotic relationship with social elements such as teaching processes and organizational management. By introducing the resilience three feature model of CAS - diversity, redundancy, and adaptability, digital resilience is deconstructed into three dimensions: robustness of technical architecture, fault tolerance of business processes, and evolution of organizational capabilities, forming the topological foundation of the evaluation system [13, 14].

Specifically, the design of the evaluation system follows the STS system analysis paradigm of "structure process result". At the structural level, the focus is on the physical architecture of the perception layer, network layer, computing power layer, etc. defined for the new infrastructure of education. By measuring indicators such as network topology robustness, it is verified whether the "digital base" meets the full element connectivity requirements of the "Guidelines for the Construction of New Education Infrastructure"; At the process level, based on the theory of educational service continuity management, attention is paid to the dynamic adaptation performance of teaching business processes in the face of digital interruption events, with a focus on evaluating process indicators such as service degradation mechanisms and path reconstruction effectiveness; At the outcome level, drawing on the evolutionary perspective of digital maturity models, forward-looking indicators such as technological iteration capability and service expansion capability are set to ensure that the evaluation system not only reflects the current resilience status, but also captures the potential for continuous improvement of the system. The research logic strictly follows the

CAS formation mechanism of "resilience emergence", achieving a balance between theoretical consistency and practical feasibility.

3. Experimental design

3.1. Campus digital resilience index system

Based on the above analysis, this article constructs a comprehensive evaluation index system for campus digital resilience, as shown in Table 1. This evaluation system revolves around the core requirements of new educational infrastructure and constructs a resilience assessment framework covering all elements of digital campus. The system design follows a three-layer logic of "basic support business guarantee development evolution". At the network infrastructure level, the reliability and resilience of digital infrastructure are ensured by monitoring the speed of network fault recovery and the efficiency of computing power allocation; In the dimension of teaching services, the focus is on evaluating the continuity of online education and the effectiveness of intelligent assistance, directly reflecting the strength of digital support for core educational functions.

As a central link, data governance not only focuses on the efficiency of cross system data flow, but also emphasizes the precise digital mapping of physical space, providing high-quality data fuel for campus digital transformation. Security management sets up a dual line of defense, requiring both rapid vulnerability repair at the technical level and emphasizing a compliance loop for privacy protection, forming a protective system that combines offense and defense. At the level of organizational collaboration, by quantifying the timeliness of emergency response and the level of digital literacy, the key role of management systems and personnel capabilities in amplifying technical efficiency is revealed. The ultimate focus is on the ability of ecological evolution, which not only examines the efficiency of technological iteration, but also evaluates the potential for service expansion, ensuring that the evaluation system has dynamic adaptability. All indicator data are taken from the existing management system of the school and collected in real-time through automated interface integration.

Table 1. Comprehensive evaluation index system for campus Digital resilience

Primary Dimension	Secondary Indicator	Tertiary Measurable Parameters	Data Source
1. Network infrastructure resilience	1.1 Network Availability	- Core Node Fault Recovery Time- Wireless AP Disconnection Rate	Campus Network Management System LogsIoT Device Monitoring Platform
	1.2 Computational Power Elasticity	- Virtualized Resource Allocation Speed- Load Balancing Hit Rate	Cloud Computing Management Platform RecordsCDN Service Provider Monitoring Report
2. Data governance resilience	2.1 Data Circulation Efficiency	- Cross - system API Call Success Rate- Data Update Latency	Campus - wide Data Platform LogsAcademic Affairs Management System Interface Records
	2.2 Digital Mirror Precision	- Physical Space Digitization Coverage Rate- Equipment Status Synchronization Rate	Campus BIM Model LibraryEquipment Asset Management System
3. Resilience of Teaching Services	3.1 Teaching Continuity Assurance	- Online Classroom Crash Rate- Teaching Resource Access Success Rate	Smart Teaching Platform MonitoringResource Server Access Logs
	3.2 Intelligent Assistance Efficiency	- Learning Situation Early Warning Accuracy Rate- Personalized Recommendation Adoption Rate	Learning Analytics System ReportTeaching Behavior Database
4. Manage collaborative resilience	4.1 Emergency Response Capability	- Contingency Plan Activation Timeliness- Multi - department Collaborative Response Speed	Emergency Management Platform RecordsOA System Process Logs
	4.2 Digital Literacy Level	- Teachers' IT Training Achievement Rate- Students' Digital Tool Proficiency	Continuing Education Credit SystemDigital Learning Platform Usage Statistics
5. Resilience of safety protection	5.1 System Robustness	- Average Vulnerability Fix Time- Backup Data Integrity	Network Security Monitoring PlatformDisaster Recovery System Inspection Report
	5.2 Privacy Compliance	- Personal Information Anonymization Rate- Data Access Audit Completeness Rate	Data Governance Platform LogsThird - party Security Assessment Report
6. Resilience of Ecological Evolution	6.1 Technology Iteration Capability	- System Upgrade Success Rate- New Technology Application Conversion Cycle	IT Construction Project LibraryTechnology Acceptance Documents
	6.2 Service Expansion Capability	- Microservice Interface Compatibility- Platform User Growth Tolerance	API Gateway Monitoring DataUser Concurrent Stress Test Report

3.2. Experimental plan design

3.2.1. Data collection

In the data preparation stage, this study used stratified cluster sampling to select samples. According to the school classification standards of the Ministry of Education, the target universities are divided into three levels: comprehensive, teacher training, and science and engineering. Five universities are randomly selected from each level, and a total of 15 sample schools are obtained. The data sources are divided into three channels. The first is structured data automatically exported from the campus information management system backend, covering 8 core indicators such as network availability and teaching continuity; The second is semi-structured data captured in real-time through the API interface of the school level data platform; The third is manually collected questionnaire survey data, mainly involving subjective evaluation indicators such as digital literacy of teachers and students.

Then standardize and preprocess the raw data. Specifically, for continuous variables such as network failure recovery time, Winsorize tail reduction method is used to handle extreme values; Perform inverse sine conversion on percentage data such as API call success rate to meet the requirements of normal distribution; The categorical variables are converted into dummy variables for processing. A unified database was established using Excel and SPSS 26.0, resulting in a panel dataset containing 540 observations spanning from September 2022 to June 2023.

3.2.2. Evaluation indicators

① Cronbach's alpha coefficient. Evaluate the consistency of internal indicators across all dimensions. Calculate the alpha coefficients of six primary dimensions using SPSS software, with quarterly observation data from 15 schools as the data source. The threshold for achieving the standard is $\alpha \geq 0.70$.

② Retest reliability (ICC). Verify the time stability of the indicator system. Select three schools to conduct two evaluations with an interval of 30 days, calculate the consistency of the total score through the correlation coefficient within the group, and use the original score matrix of the two evaluations as the data source. The threshold for achieving the standard is ICC ≥ 0.80.

③ Content Validity Index (CVI). Confirm the correlation between indicators and theoretical concepts. Measurement method: Invite 5 experts to rate the necessity of 36 indicators, calculate the proportion of experts with a single item content validity (I-CVI)=score ≥ 3, take the average of the overall CVI, and use the expert rating table as the data source. The threshold for achieving the standard is I-CVI ≥ 0.80.

④ Criteria related validity. Check the correlation strength between the indicator system and external standards. Using the "Smart Campus Star Certification" issued by the provincial education department as the criterion, calculate the Pearson correlation coefficient between the total score of the indicator system and the star rating. The data source is matching data from 10 schools, and the compliance threshold is $r \geq 0.65$.

⑤ Independent sample t-test. Verify the ability of the indicator system to distinguish between high and low level schools. Sort the 15 schools according to their total scores, with the top 30% being the high group and the bottom 30% being the low group. Compare the mean differences between the two groups in core indicators such as network recovery time. The data source is the grouping indicator dataset, and the compliance threshold is $t \geq 2.10$.

⑥ Mann Whitney U test. Test the discriminant validity of the indicator system for different types of schools. Divide the sample into key schools (N=7) and regular schools (N=8), compare the distribution differences of the total scores between the two groups, and use school classification labels and total score data as the data source. The threshold for achieving the standard is $Z \geq 2.58$.

⑦ Logistic regression AUC value. The ability of the evaluation index system to predict educational service interruption events. A regression model was constructed with "whether there was a major teaching interruption" as the dependent variable and six dimension scores as independent variables. AUC values were calculated using ROC curves, with historical event records and indicator data from 12 schools as the data source. The threshold for achieving the standard is AUC ≥ 0.75.

⑧ Regression model chi square value. Verify the significance of the overall prediction model. Measurement method: Perform logistic regression analysis in SPSS and output the fitted chi square value of the model. The data source is the same as AUC test, and the threshold for meeting the standard is $\chi^2 \geq 20.0$.

4. Results analysis

4.1. Reliability and validity testing

The reliability and validity test results of the indicator system are shown in Table 2. The digital resilience campus scale constructed by our research institute performs well in terms of reliability, reflecting high internal consistency. The Cronbach's alpha coefficient of the network infrastructure dimension is 0.82, and the alpha coefficient of the data governance dimension is 0.79, both exceeding the recommendation threshold of 0.70, indicating good consistency between items and the ability to characterize their latent variables in a homogeneous manner. The reliability of the test retest was significantly higher than the 0.85 standard, further indicating that the scale can stably reflect the characteristics of the subjects when repeated at different time points. However, the alpha coefficient of the teaching service dimension is only 0.68, slightly lower than the lower limit of 0.70, indicating that there are still shortcomings in the accuracy of the expression of this dimension, which may be due to the fact that the items cross online and offline mixed contexts, leading to misunderstandings among the participants.

In terms of validity testing, this scale also meets the predetermined standards. A content validity index above the expert consensus threshold of 0.80 indicates that the selected items can comprehensively cover the key dimensions of digital resilience campus construction. The criterion related validity obtained through Pearson correlation analysis was 0.72, which is significantly higher than the acceptable level of 0.65, indicating a medium to high degree of positive correlation between the scale score and existing mature scales. This empirically verifies the effective predictive ability of the scale for the digital resilience campus concept.

The comprehensive reliability and validity test results show that the scale in this study has a high measurement quality, laying a more solid measurement foundation for subsequent validation.

Table 2. Reliability and validity testing

Test Type	Test Indicator	Result	Standard	Judgment
Reliability Test	Network Infrastructure α Coefficient	0.82	≥0.70	✓
	Data Governance α Coefficient	0.79	≥0.70	✓
	Teaching Service α Coefficient	0.68	≥0.70	✕
	Test - retest Reliability (Pearson r)	0.89*	≥0.85	✓
Validity Test	CVI	0.83	≥0.80	✓
	Criterion - related Validity (Pearson r)	0.72**	≥0.65	✓

4.2. Differentiation test

The results of the discrimination test are shown in Table 3. The discriminant test method used in this study can effectively distinguish the performance differences of participants in various dimensions of digital resilience campus, and the statistical results have reached a significant level, indicating that the scale has good discriminant power.

Independent sample t-test was conducted using network recovery time as a representative indicator, and the difference between groups was significant, far below the significance level of 0.05. This indicates that there is a substantial difference between the high and low groups in terms of emergency recovery speed for network failures. Further calculation of Cohen's d=0.82, which belongs to the category of large effect quantity, indicates that this indicator is not only statistically significant, but also can clearly distinguish the network resilience level of different subject groups in practical applications, and has strong practical significance.

Use Mann Whitney U test for the total score of the scale to compensate for assumptions such as non normal distribution or uneven variance. The results showed that Z=2.93, p=0.003, also significantly lower than 0.05, indicating a systematic difference in the distribution of total scores between the high and low groups. This non parametric test still yielded consistent conclusions without relying on normality assumptions, further verifying the robustness of the overall score of the scale in distinguishing populations with different levels of resilience.

The dual evidence of independent sample t-test and Mann Whitney U test jointly proves that the digital resilience campus scale constructed in this study has good discriminative power in key dimensions and overall score.

Table 3. Discrimination test

Test Method	Group Comparison	Statistic	Significance	Effect Size	Judgment
Independent - samples t - test	Network Recovery Time	t = 3.41	p = 0.002	Cohen's d = 0.82	✓
Mann - Whitney U test	Total Score	Z = 2.93	p = 0.003	-	✓

4.3. Validation of predictive validity

The validation results of predictive validity are shown in Table 4. The digital resilience campus scale constructed by our research institute has shown convincing results in the validation of predictive validity, providing empirical support for the application value of the scale. By constructing a logistic regression model to predict the likelihood of target events based on scale scores, the area under the ROC curve is 0.78, which is higher than the industry recommendation lower limit of 0.75, indicating that the model's ability to distinguish positive and negative samples is in the "good" range. This result means that the scale score can accurately predict whether the sample has strong numerical resilience in binary classification, and its prediction probability has high discriminative power.

The overall goodness of fit of the model was obtained through chi square test, with a value of χ^2=24.7 and p<0.001, indicating that the explanatory variable set of the model significantly improved the explanatory power of the dependent variable compared to the null model. This statistical significance not only reflects that each dimension of the scale does contribute to information gain in the prediction process, but also provides a solid credibility guarantee for the overall validity of the model from a statistical perspective.

Based on the dual evidence of AUC and chi square test, the scale in this study not only has good discriminative performance in terms of predictive validity, but also shows significant advantages in model fitting. From this, it can be seen that the scale is not only suitable for descriptive research, but can also be used as a predictive tool in practice to conduct prospective evaluations of campus digital resilience levels and provide quantitative indicators for decision support systems of school managers.

Table 4. Validation of predictive validity

Predictive Model	Evaluation Indicator	Result	Standard	Judgment
Logistic Regression Model	AUC Value	0.78	≥0.75	✓
Model Chi - square Test	$\chi^2 = 24.7$	$p < 0.001$	-	✓

5. Conclusion

Based on the research results, the main conclusions of this study are as follows. (1) The digital resilience campus can be composed of three dimensions: network infrastructure, data governance, and teaching services, and its internal logic follows the path of "hardware platform application" hierarchical collaboration; (2) After reliability testing, the internal consistency between network infrastructure and data governance dimensions is good, and the test retest reliability also indicates that the scale has high stability in testing. However, the "teaching service" dimension still needs item optimization; (3) The validity test and discriminant test jointly validated the content coverage and sample discrimination function of the scale; (4) The predictive validity model shows that the score of this scale has good binary discrimination and explanatory power for the response ability of campus system faults. The digital resilience campus measurement tool constructed by the research institute has shown high application value at both theoretical and empirical levels, laying a solid foundation for cross sample comparison.

Based on the above conclusions, the following suggestions are proposed to promote the systematic construction of a digital resilient campus. (1) We should continue to strengthen the construction of network infrastructure and increase investment in edge computing nodes to further shorten the network recovery time and stabilize the resilience of the hardware layer; (2) We need to improve the data governance mechanism and introduce stricter standardized monitoring in the data collection, cleaning, storage, and sharing processes to ensure data quality; (3) Regarding the dimension of "teaching services", it is necessary to conduct expert consensus discussions on existing items and revise them through pre survey feedback. New projects with high homogeneity should be added to enhance the internal consistency of this dimension; (4) It is suggested that the education regulatory authorities and school level managers embed this scale into routine performance evaluations, combine it with predictive validity model outputs, and form a digital resilience monitoring dashboard to provide quantitative basis for emergency event assessment; (5) We should conduct research on the scalability verification of schools in multiple regions and types, and further explore the path relationships and mediating effects between various dimensions through structural equation modeling, providing more universal empirical guidelines for theoretical deepening and practical promotion. The coordinated implementation of the above measures will promote the systematic upgrading of digital resilient campuses in terms of hardware facilities, platform governance, and teaching services, and help achieve the comprehensive goals of new educational infrastructure.

Although significant progress has been made in constructing and validating the Digital Resilience Campus Scale in this study, there are still several limitations that cannot be ignored. On the one hand, the sample sources are mainly concentrated in small and medium-sized universities in several provinces and cities, and the representativeness is still insufficient, which may affect the external validity of the scale in different regional cultural backgrounds. On the other hand, although the items in the dimension of teaching services have been preliminarily revised, the reliability indicators have not yet reached the ideal threshold, indicating that this dimension still needs to deepen its concepts and refine its items in indicator design.

In response to the above limitations, future research can expand and deepen through multidimensional approaches. Firstly, the sample coverage should be expanded to include different regions, levels, and Sino foreign cooperative education institutions, and the cross-cultural applicability of the scale should be improved through multi center large sample verification; Secondly, by combining system logs with objective monitoring indicators, a multi-source collaborative measurement system is constructed to mitigate the interference of self reporting bias; Thirdly, regarding the dimension of teaching services, it is recommended to introduce a dual perspective of cognitive load measurement and teaching satisfaction evaluation, refine the items of online teaching collaboration, blended learning support, and intelligent auxiliary learning services, in order to enhance the internal consistency of this dimension.

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