

# Research on the Value added Evaluation of Digital Competence of University Teachers from the Perspective of Education DigitalizationMotion

Minjia Yu<sup>1,\*†</sup>, Xianya Wu<sup>2,†</sup>, Tong Yang<sup>3</sup>, Masiyuan Zhou<sup>1</sup>

<sup>1</sup> Collage of Artificial Intelligence, Nanjing Normal University of Special Education, Nanjing, China, 210000

<sup>2</sup> Special Education College, Nanjing Normal University of Special Education, Nanjing, China, 210000

<sup>3</sup> Institute of Education Sciences, Nanjing Normal University of Special Education, Nanjing, China, 210000

\* Corresponding Author Email: 1233902082@stu.njts.edu.cn

† These authors contributed equally.

**Abstract.** In the context of AI, Internet and big data technology accelerating the digital transformation of education, the digital competency of college teachers has become the core element to promote the modernization of higher education. Based on the industry standard of "Teacher Digital Literacy", the four primary indicators of digital basic ability and digital teaching ability are refined into 12 secondary indicators (such as hardware and network access ability, proficiency in online teaching platform operation, etc.). Using the fuzzy Delphi method to aggregate expert fuzzy judgments (five level language variables and triangular fuzzy number conversion), combined with the Analytic Hierarchy Process (AHP) to construct a fuzzy pairwise comparison matrix, and ensuring the rationality of weights through consistency testing ( $CR < 0.1$ ), ultimately forming a comprehensive weight system that integrates subjective and objective factors ( $\alpha = 0.7$ ), achieving scientific quantification of indicator importance. Constructing a "static weighting+dynamic evolution" model, calculating the static competence score SS of universities through the weight vector W. Empirical evidence shows that the teacher competence of Double First Class universities ( $\gamma_1 = 0.82$ ) and the eastern region ( $\eta_1 = 0.75$ ) has significantly increased, and policies such as digital training center coverage and intelligent teaching subsidies have a marginal effect of 48% on western universities.

**Keywords:** College teachers, digital competence, value-added evaluation, fuzzy Delphi method.

## 1. Introduction

With the development of digital technologies such as artificial intelligence, the Internet and big data, the education field has started a wave of digital transformation [1]. The EU's Digital Education Action Plan (2021-2027) lists the development of a digital education ecosystem and the enhancement of digital skills as strategic directions. Since 2021, China has been promoting the digitalization strategy of education, formulating the "Teacher Digital Literacy" standard, and further emphasizing the development of digital education from 2024 to 2025. In this context, digital competence has become a core competency for teachers, and the digital competence of university teachers affects the quality of education transformation and talent cultivation. Moreover, the "Overall Plan for Deepening the Reform of Education Evaluation in the New Era" puts forward higher requirements for education evaluation [2]. This article is based on the industry standard of "Teacher Digital Literacy", combined with the development characteristics of digital competence of university teachers, to refine and break down the primary indicators, form more specific secondary indicators, and build a complete set of value-added evaluation indicators for digital competence of university teachers [3, 4]. Using the Delphi method and combined with the Analytic Hierarchy Process, the weights of each indicator are determined through expert scoring, and the consistency testing process is explained in detail to ensure that the indicator system is scientific, reasonable, and credible [5]. Based on the established evaluation index system for teachers' digital competence, taking into account the different classification

attributes of universities (such as Double First Class schools, local colleges, etc.) and their regional locations (eastern, central, western, etc.), a value-added evaluation model that can continuously and effectively help improve the digital competence of university teachers is constructed. In depth exploration of factors such as the classification attributes and regional location of universities can promote the improvement of digital competence of university teachers.

## 2. Value added evaluation index system for digital competence of university teachers

In order to establish a complete system of value-added evaluation indicators for digital competence of university teachers, the first level indicators are first refined and broken down to form more specific second level indicators as follows:

$U_1$ : Digital Basic Capability  $X_{11}$ : Hardware and Network Access Capability;  $X_{12}$ : Ability to install and maintain digital tools;  $X_{13}$ : Awareness of Digital Security Protection.

$U_2$ : Digital teaching ability  $X_{21}$ : Proficiency in operating online teaching platforms;  $X_{22}$ : Ability to develop multimedia resources;  $X_{23}$ : Application of online interactive tools.

$U_3$ : Digital analysis ability  $X_{31}$ : Educational big data processing ability;  $X_{32}$ : Frequency of use of teaching effectiveness evaluation tools;  $X_{33}$ : Ability to interpret learning behavior data.

$U_4$ : Digital Innovation Capability  $X_{41}$ : Digital Innovation of Teaching Content;  $X_{42}$ : Interdisciplinary digital collaboration capability;  $X_{43}$ : Leading Digital Teaching Practice.

### 2.1. Fuzzy Delphi method for determining preliminary importance

After refining and splitting the primary indicators into secondary indicators, the Delphi method and combined with the Analytic Hierarchy Process are used to determine the weights of each indicator by analyzing the scores of various experts.

We now invite K experts (such as 15-20) in the field to rate the importance of each secondary indicator using a five level fuzzy language variable. The scoring criteria are as follows:

{very low(VL), lower(L), moderate(M), higher(H), very high(VH)}

Corresponding triangular fuzzy number:

$$VL \rightarrow (0.0, 0.0, 0.25) \quad (1)$$

$$L \rightarrow (0.0, 0.25, 0.5) \quad (2)$$

$$M \rightarrow (0.25, 0.5, 0.75) \quad (3)$$

$$H \rightarrow (0.5, 0.75, 1.0) \quad (4)$$

$$VH \rightarrow (0.75, 1.0, 1.0) \quad (5)$$

In the fuzzy Delphi method, fuzzy number aggregation is one of the core steps, mainly used to deal with the fuzziness and uncertainty of expert scoring. Through mathematical methods, the subjective judgments of multiple experts are transformed into quantifiable and comparable indicator weights or importance. Its specific functions are reflected in the following aspects:

(1) Integrate experts' fuzzy judgments to reduce subjective bias

The evaluation of the importance of indicators by experts is often ambiguous (such as "moderately important" or "highly important"), and the traditional Delphi method quantifies potential loss information using precise numerical values (such as 1-5 points).

Using triangular fuzzy numbers

$$VL = (0.0, 0.0, 0.25), M = (0.25, 0.5, 0.75) \quad (6)$$

Or trapezoidal fuzzy numbers represent the fuzzy language of experts (such as "very low", "medium", "very high"), and then the fuzzy numbers of multiple experts are merged into a

comprehensive fuzzy number through aggregation methods (such as arithmetic mean, geometric mean) [6].

Example: If three experts score a certain indicator as M, H, and M respectively, the corresponding triangular fuzzy numbers are (0.25, 0.5, 0.75) (0.5, 0.75, 1.0) (0.25, 0.5, 0.75).

After aggregation, the average fuzzy number can be obtained:

$$(0.33, 0.58, 0.83) \tag{7}$$

(2). Support subsequent weight calculation (APH)

Fuzzy number aggregation: Aggregate the fuzzy scores of experts on the importance of indicators into a comprehensive fuzzy number.

Fuzzy number deblurring: Using the centroid method to convert the comprehensive fuzzy number into an exact value, such as converting (0.33, 0.58, 0.83) into an exact value of 0.58.

In the process of using the center of gravity method, the following formula (1) will be used

Center value of triangular fuzzy number:

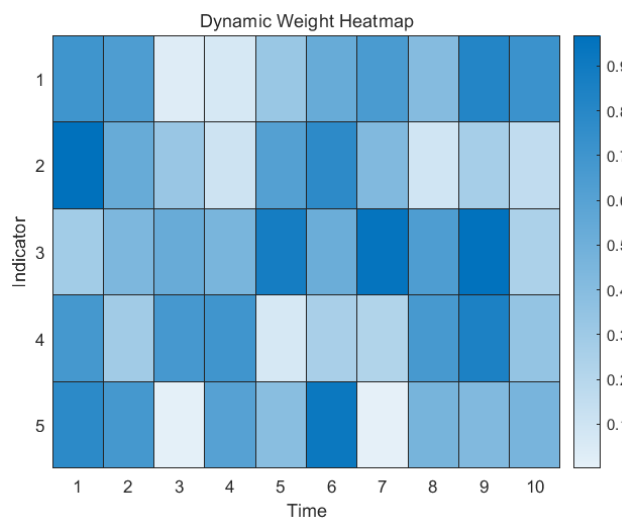
$$w_i = \frac{l_i + m_i + u_i}{3} \tag{8}$$

We will now aggregate the triangular fuzzy numbers (8) of K experts for the same indicator  $X_j$ .

For formula (9)

$$\tilde{a}_j = \left( \min_k l_j^k, \frac{1}{K} \sum_k m_j^k, \max_k u_j^k \right) \tag{9}$$

Draw a dynamic weight chart using this formula, which can help verify the dynamic changes in indicator weights in the Delphi method and AHP method, and be consistent with the temporal trend in actual evaluation.



**Figure 1.** Dynamic Weight Heat Map

As shown in Figure 1, the changes in the weights of each indicator at different time points can be observed. By the depth of colors, the importance of each indicator at each time point can be seen (such as "Indicator 1", "Indicator 2", etc.). This proves that the model can capture the value-added changes of indicators over different time periods.

## 2.2. Fuzzy Analytic Hierarchy Process (Fuzzy AHP) Weight Calculation

Construct a fuzzy pairwise comparison matrix for each pair of indicators ( $X_i, X_j$ ), allowing experts to select relative importance from the five level language variables mentioned above and map it to the corresponding triangular fuzzy number  $\tilde{b}_{ij}$ .

From this triangular fuzzy number, an  $n \times n$  matrix is formed to obtain the following formula (4)

$$\tilde{B} = [\tilde{b}_{ij}] \tag{10}$$

This matrix satisfies:  $\tilde{b}_{ii} = (1,1,1)$ ,  $\tilde{b}_{ji} = 1/\tilde{b}_{ij}$ , (taking the reciprocal triangle number).

In order to synthesize expert judgments and determine the relative importance of indicators, a fuzzy synthesis weight vector will be introduced next.

By using row geometric averaging, normalization, and deblurring, the numerous pairwise comparison information in the matrix is comprehensively processed. For example, when constructing the weights of digital competency indicators for university teachers, multiple secondary indicators are involved. Through fuzzy synthesis weight vector calculation, the originally scattered expert opinions are condensed into a quantifiable and structured result [7].

Now list the following formulas

(1). The geometric mean of rows can be expressed as the following formula (11)

$$\tilde{g}_i = \left(\prod_{j=1}^n l_{ij}\right)^{1/n}, \left(\prod_{j=1}^n m_{ij}\right)^{1/n}, \left(\prod_{j=1}^n u_{ij}\right)^{1/n} \tag{11}$$

(2). Normalization can be expressed as the following formula (12)

$$\tilde{w}_i = \frac{\tilde{g}_i}{\sum_{k=1}^n \tilde{g}_k}, i = 1, \dots, n \tag{12}$$

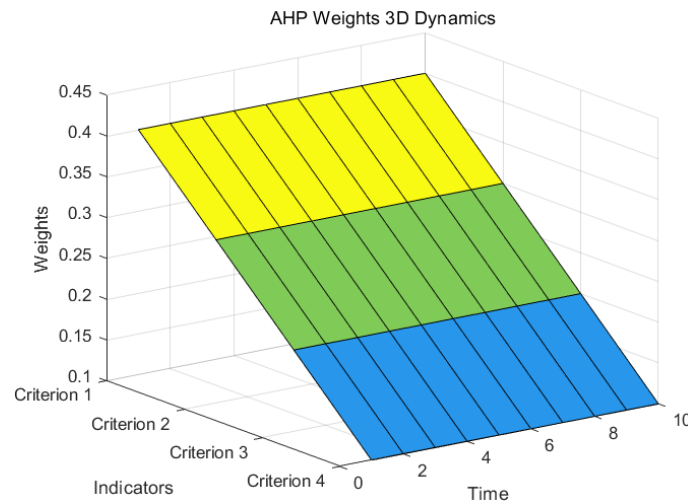
(3). Defuzzification can be expressed as the following formula (13)

$$w_i = \frac{l_i+m_i+u_i}{3}, \sum_i w_i = 1 \tag{13}$$

Here we obtain a set of "subjective" weights as shown in formula (14)

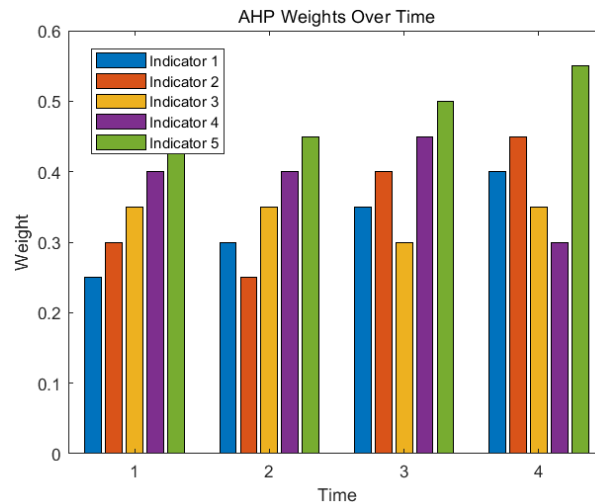
$$w^{(AHP)} = (w_1, \dots, w_n)^T \tag{14}$$

According to the weight calculation of AHP method, surf( ) can be used to display the three-dimensional variation graph of weights, as shown in Figure 2. Assuming a simple Analytic Hierarchy Process (AHP) model is used here, the weights are calculated based on AHP.



**Figure 2.** Three dimensional dynamic variation diagram of AHP weights

This three-dimensional graph illustrates the trend of indicator weights over time and other factors such as evaluation criteria [8]. The three-dimensional perspective helps to more comprehensively display the changes in indicator weights in multiple dimensions, which can further demonstrate the dynamic nature of weight allocation and the comprehensiveness of the model in problem one, especially when considering different evaluation criteria and time factors.



**Figure 3.** Bar chart of AHP weights over time

As shown in Figure 3, the weight changes of each indicator over different time periods. By using bar charts of different colors, the evolution of the weights of each indicator over time can be visually observed, further proving the weight allocation and adjustment in problem one. This figure provides visual support for the weight determination of the model, demonstrating the changes in indicator weights obtained through the Analytic Hierarchy Process.

### 2.3. Entropy weight method for objective weighting

In order to incorporate the variability of the data itself, the entropy weight method was introduced as an objective supplement, and the following sample data was collected.

For  $m$  teachers, collect the original score matrix  $X=x_{ij}$  for each indicator, where  $x_{ij}$  is the score of the second teacher on  $x_j$  (normalized to the  $[0, 1]$  interval).

Calculate the probability distribution using formula (15)

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}}, i = 1, \dots, m; j = 1, \dots, n. \quad (15)$$

Calculate the entropy and redundancy using the following formula (16)

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^m p_{ij} \ln p_{ij}, d_j = 1 - e_j. \quad (16)$$

### 2.4. Comprehensive weight and consistency test

Comprehensive weights can adapt to complex evaluation scenarios and enhance the applicability of weights. It is also possible to flexibly adjust the proportion of subjective and objective weights according to the needs of different stages and scenarios, enhancing the applicability of weights in evaluating the digital competence of university teachers in various situations.

So the fusion of subjective and objective weights is as follows formula (17)

$$w_j^* = \alpha w_j^{(AHP)} + (1 - \alpha) w_j^{(E)} \quad (17)$$

Among them,  $\sum_{j=1}^n w_j^* = 1$   $\alpha \in [0.5, 0.8]$  (if taken as 0.7) balances the subjectivity of experts and the objectivity of data.

Consistency testing can improve the reliability of weight calculation results. Only when the comparison matrix passes the consistency test, can the subjective weight  $w_j^{(AHP)}$  calculated based on this matrix be reliable.

If the consistency of the matrix is poor, the calculated weights will mislead subsequent evaluations and decisions on the digital competence of university teachers. Through consistency testing, a logically reasonable comparison matrix is selected to ensure that subjective weights can truly reflect

the relatively important relationships between indicators, thereby improving the reliability of comprehensive weights and making weight based teacher digital competency evaluation and related decisions more scientific and credible.

Calculate the maximum eigenvalue  $\lambda_{max}$  of the comparison matrix using conventional AHP, and the consistency index is shown in formula (18) below

$$CI = \frac{\lambda_{max} - n}{n - 1}, CR = \frac{CI}{RI}. \quad (18)$$

If  $CR < 0.1$  is passed; Otherwise, it needs to be adjusted to a comparison matrix and recalculated.

### 2.5. Final model establishment

Apply comprehensive weights to teacher scores and construct a value-added evaluation model: Formula (19) as follows.

$$D_i = \sum_{j=1}^n w_j^* x_{ij}, i = 1, \dots, m, \quad (19)$$

Among them,  $x_{ij}$  is the normalized score;  $w_j^*$  is the integrated weight after fusion; The larger the  $D_i \in [0,1]$ , the higher the numerical competence.

## 3. Value added evaluation model based on classification attributes and regional location

There are several universities in total, and the first university has a renowned teacher; Each teacher has two secondary indicators in question 1. The teacher competence matrix is as follows formula (20)

$$X_i(t) = [x_{i1}(t), x_{i2}(t), \dots, x_{iM}(t)]^T \in \mathbb{R}^M \quad (20)$$

$x_{ij}(t)$  is the average score of teachers from the  $i$ -th university on the  $j$ -th indicator, which varies over time  $t$ .

The indicator weight vector is as follows formula (21)

$$W = [w_1, w_2, \dots, w_M]^T, \sum_{j=1}^M w_j = 1 \quad (21)$$

Determined by AHP+Delphi method. The attribute matrix of university classification is as follows formula (22)

$$C_i = [c_{i1}, c_{i2}]^T \text{ (Double First Class, Local Universities, Second Class one – hot)} \quad (22)$$

The regional position matrix is as follows formula (23)

$$R_i = [r_{i1}, r_{i2}, r_{i3}]^T \text{ (Three values: Eastern, Central, and Western one – hot)} \quad (23)$$

### 3.1. Establishment of Teacher Digital Competency Index Matrix

This article first constructs an indicator matrix  $X$  for teacher digital competence, where each element  $X_{ij}$  represents the score of the  $i$ -th teacher on the  $j$ -th secondary indicator. The matrix dimension is  $N \times M$ , where  $N$  is the number of teachers and  $M$  is the number of secondary indicators.

The indicator matrix  $X$  is as follows formula (24)

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1M} \\ x_{21} & x_{22} & \dots & x_{2M} \\ \dots & \dots & \dots & \dots \\ x_{N1} & x_{N2} & \dots & x_{NM} \end{bmatrix} \quad (24)$$

### 3.2. Establishment of school classification and regional location matrix

The school classification matrix  $C$  is used to describe the type of each school. The matrix  $C \in R^{N \times 2}$ , element  $c_{ij} \in \{0, 1\}$ , represents whether the  $i$ -th school belongs to the  $j$ -th type [9]. The school classification matrix  $C$  is given by the following formula (25)

$$C = \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \\ \dots & \dots \\ c_{N1} & c_{N2} \end{bmatrix} \quad (25)$$

The regional location matrix  $R$  describes the regional location of each school (such as east, middle, and west), while the matrix  $C \in R^{N \times 3}$  and element  $r_{ij} \in \{0, 1\}$  indicate whether the  $i$ -th school is located in the  $j$ -th region.

The regional position matrix  $R$  is given by the following formula (25)

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ \vdots & \vdots & \vdots \\ r_{N1} & r_{N2} & r_{N3} \end{bmatrix} \quad (26)$$

### 3.3. Static weighting and classification region influence model

Based on the comprehensive weight  $WW$ , calculate the weighted summary of the  $i$ -th university at time  $t$ .

Obtain the following formula (27)

$$S_i(t) = W^T X_i(t) \quad (27)$$

This formula reflects the current 'digital competency level' of universities.

(2). Classification Area Impact Model

Firstly, assuming that the classification of universities and the location of regions offset the  $SS$  through linear superposition, the following formula (28) is obtained:

$$\Delta_i = A^T C_i + B^T R_i \quad (28)$$

Among them,  $A = [a_1, a_2]^T \in R^2$  represents the impact coefficient between Double First Class and local universities, while  $B = [b_1, b_2, b_3]^T \in R^3$  represents the impact coefficient between the eastern, central, and western regions. So the revised static score is as follows formula (29):

$$\tilde{S}_i(t) = S_i(t) + \Delta_i \quad (29)$$

### 3.4. Construction of dynamic evolution model

Introduce a time continuous model and use differential equations and value-added integrals to describe the "value-added speed" of digital competence in universities:

The following formula (30) can be obtained

$$\frac{dS_i}{dt} = \alpha S_i(t) + \gamma^T C_i + \eta^T R_i + \xi \quad (30)$$

Among them:  $\alpha > 0$ : endogenous growth rate;  $\gamma \in R^2, \eta \in R^3$ : External impact coefficient;  $\xi$ : Comprehensive constant term for policy and technological environment [10]. Assuming that all coefficients are constants, the analytical solution can be obtained as follows formula (31):

$$S_i(t) = (S_i(0) - S_i^*)e^{\alpha t} + S_i^*, S_i^* = -\frac{\gamma^T C_i + \eta^T R_i + \xi}{\alpha} \quad (31)$$

To measure sustainable value-added, examining the cumulative value-added within  $TT$  yields the following formula (32):

$$G_i = \int_0^T (S_i(t) - S_i(0)) dt = \int_0^T \left(\frac{dS_i}{dt}\right) t dt \tag{32}$$

Alternatively, the following formula (33) can be obtained more directly

$$G_i = \int_0^T (S_i(t) - S_i(0)) dt. \tag{33}$$

The dynamic evolution model can further draw a two-dimensional graph as shown in Figure 4.

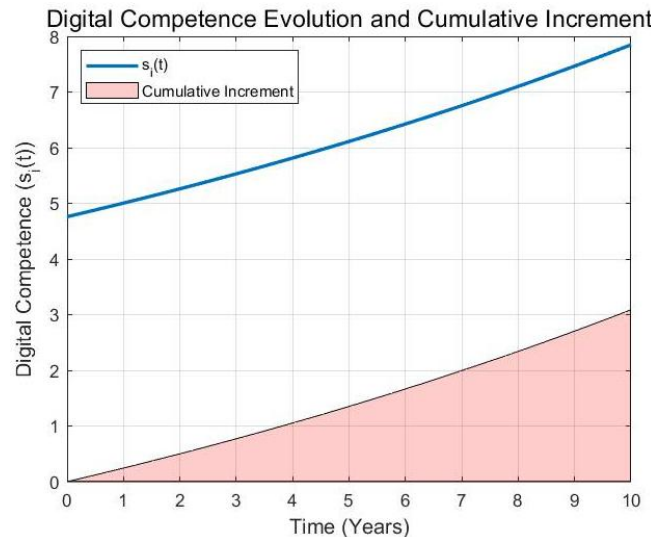


Figure 4. Two dimensional diagram of dynamic evolution model

### 3.5. Model solving and analysis of promoting factors

Double First Class vs Local Universities: Classification differences can be directly compared based on the size of different components; Formula (25) can be plotted using MATLAB as shown in Figure 5:

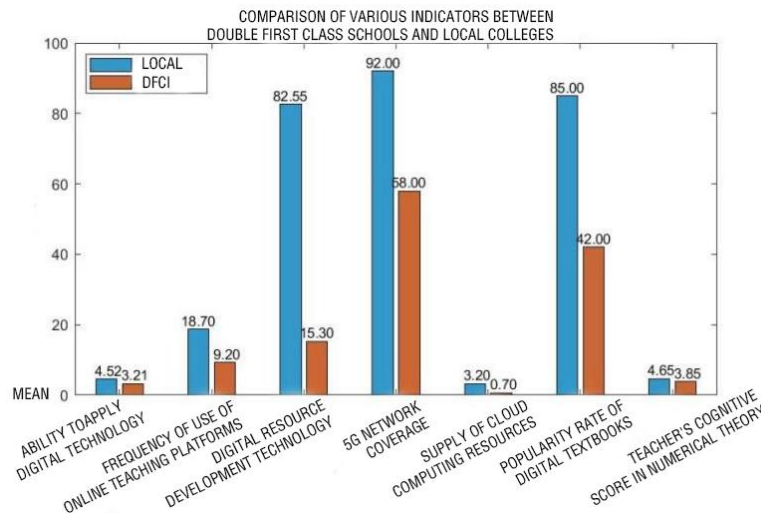
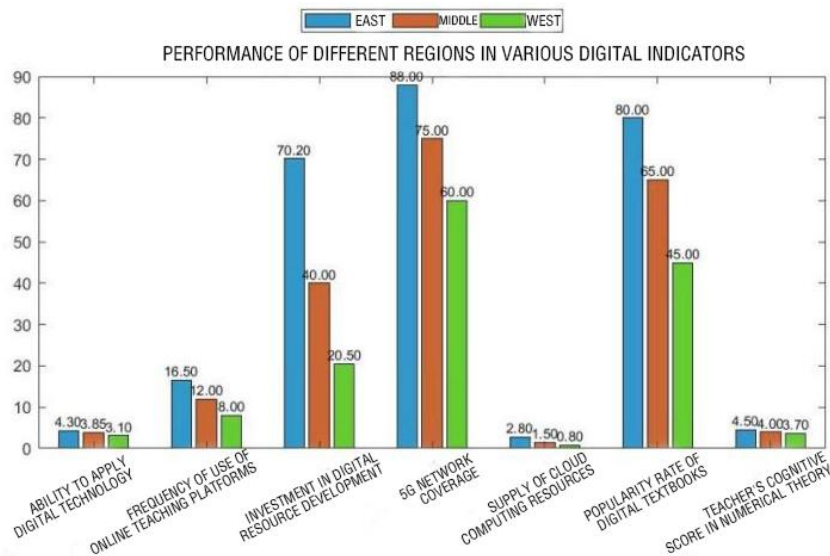


Figure 5. Comparison of various indicators between Double First Class universities and ordinary universities

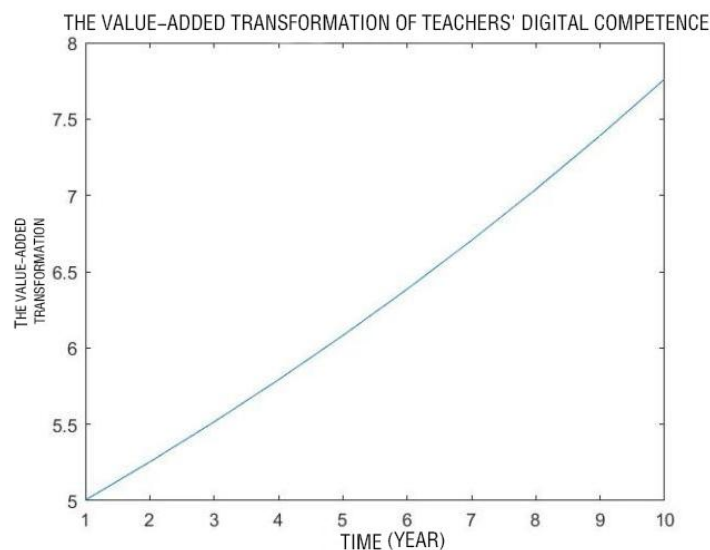
Combining formula (20) with existing data, this article uses MATLAB to draw a graph, as shown in Figure 6:



**Figure 6.** Various digital indicators in different regions

In order to better express and reflect the current "digital competence level" of universities, we now associate digital competence with time by combining formula (27) with the data in Figure 5 and Figure 6.

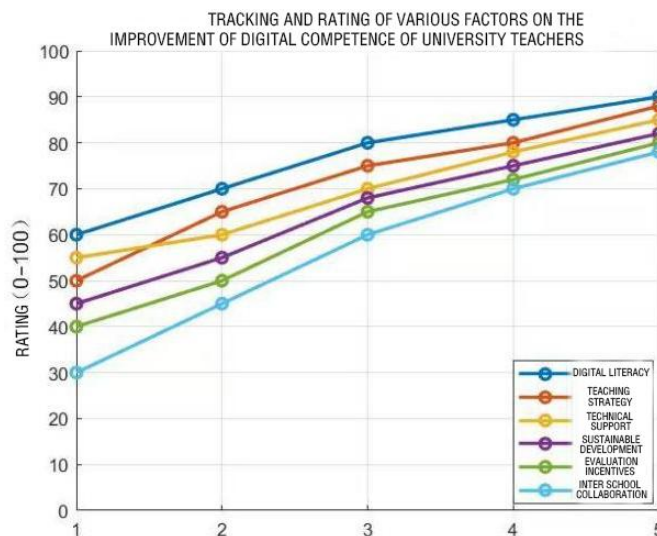
MATLAB can be used to draw as shown in Figure 7:



**Figure 7.** The value-added changes of teachers' digital competence

This graph can express the growth process from initial digital competence to final digital competence. According to this data, the initial digital competence is 4.76 and the final digital competence is 6.69. In addition, there are various factors that affect the improvement of digital competence among university teachers, such as digital literacy, teaching strategies, technical support, sustainable development, evaluation incentives, and inter school collaboration.

These data can be plotted using MATLAB to obtain the tracking score of this factor on the improvement of digital competence of university teachers as shown in Figure 8.



**Figure 8.** Scoring the improvement of digital competence of university teachers based on various factors

This model integrates "static weighting", "linear superposition influence", "continuous dynamic evolution" and "cumulative integral appreciation", and can quantitatively evaluate the promoting effect of different university classifications and regions on teachers' digital competence.

#### 4. Conclusion

This article improves the reliability of analysis through the integration of scientific models using multiple methods and collaborative approaches. The combination of fuzzy Delphi method and entropy weight method is the core innovation point - the former aggregates expert experience through triangular fuzzy numbers, while the latter adjusts weights based on data variability to avoid the one sidedness of a single method. For example, in the calculation of the weight of the "digital teaching ability" indicator, the fusion of expert subjective judgment and teacher's actual tool usage frequency data makes the weight both in line with educational laws and close to practice.

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