International Journal for Housing Science and Its Applications
Publish August 6, 2025. Volume 46, Issue 3 Pages 7663-7673

https://doi.org/10.70517/ijhsa463657

Influential factors of digital ethics literacy among elementary and secondary pre-service teachers: an empirical analysis based on logistic regression modeling

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Abstract The widespread use of digital technology has brought new ethical challenges to the field of education. As future educators, the digital ethical literacy of primary and secondary pre-service teachers is crucial to the overall development of students. This study used questionnaire survey method and logistic regression model to analyze the influencing factors of digital ethical literacy of primary and secondary pre-service teachers. The study was conducted in Southwest China, and a total of 1524 questionnaires were collected, with a valid sample of 1466 and an effective rate of 96.19%. The study constructed an ordered multicategorical logistic regression model to test the influence of variables such as teachers' personal characteristics, educational background and work environment on digital ethical literacy. The results showed that the factors influencing digital ethical literacy were ranked as follows: level of education, years of professional study, target teacher title, subject taught, number of trainings, monthly income, region taught, province taught, class structure, and number of students. Mathematics teachers had the highest digital literacy, with a mean value of 4.21; urban teachers' digital literacy (4.12) was higher than that of counties and towns (4.01) and rural teachers (3.67); and those who had received more than 10 trainings had the highest digital literacy, at 4.35. This suggests that improving pre-service teachers' digital ethic literacy requires strengthening professional education and training, paying attention to regional differences, increasing practical experience, and conducting targeted trainings. This study is of great significance for improving the digital ethics literacy training system for pre-service teachers and promoting educational equity.

Index Terms pre-service teachers, digital ethics literacy, influencing factors, logistic regression model, number of trainings, educational equity

I. Introduction

The rapid development of digitalization is profoundly changing people's production, life and even learning styles. Especially in the field of education, as an important disseminator of educational information, the development of teachers' digital literacy has become a key link in the process of digital transformation of education [1]. In order to implement the comprehensive deepening of the construction of teachers in the new era, teachers should take the initiative to adapt to new technological changes such as informatization and artificial intelligence [2]. To this end, the deep integration of intelligent technology and education and teaching collides with pre-service teachers' own learning needs, providing a solid social environment and learning motivation foundation for the cultivation of pre-service teachers' intelligent education literacy [3]-[5].

As the key force of the future teaching force, primary and secondary pre-service teachers have high potential for digital literacy and digital education needs [6]. They will play an important role in all levels and aspects of education in the future, and will play an important role in the implementation and promotion of digital education, and the development of their digital literacy is an important guarantee for their future educational and teaching activities when they embark on teaching positions [7]-[9]. Due to the specificity of the role of pre-service teachers in primary and secondary schools, the digital literacy they should have is not only the universal digital literacy they need as students, but also the digital literacy they need as teachers and knowledge transmitters [10], [11]. In the context of digital education, if primary and secondary pre-service teachers are difficult to develop digital literacy, it will affect the development of the future teaching force, unable to adapt to the future needs of teaching, and then hinder the professional development of teachers [12], [13]. Therefore, it is crucial to explore the influencing factors that affect the digital literacy of primary and secondary pre-service teachers.

Digital technology is profoundly changing the shape of education and teaching mode, and teachers' digital literacy has become a key competency to support the innovative development of education. As a core component of digital literacy, digital ethical literacy is related to whether teachers can make reasonable ethical judgments and responsible behavioral choices in the digital education environment. As an important reserve of future educators, it is particularly important for pre-service teachers to cultivate and enhance their digital ethical literacy. Research shows that teachers' digital ethical literacy directly affects the rationality of their educational and teaching behaviors, which in turn affects students' learning experience and digital literacy development. At present, digital education has penetrated into all aspects of basic education, and teachers not only need to master the ability to apply digital technology, but also need to have the awareness of digital ethics and the ability to make judgments, in order to ensure fairness and respect in the education process. However, the development of pre-service teachers' digital ethical literacy is influenced by a variety of factors, which include both the knowledge background and skill reserves at the individual level, as well as the supportive conditions and training opportunities provided by the external environment. Identifying these key influencing factors is important for the development of effective digital ethics education strategies for pre-service teachers. Existing studies at home and abroad have focused on teachers' digital technology application ability and digital teaching practices, and there is a relative lack of research on digital ethical literacy, especially on the factors influencing pre-service teachers' digital ethical literacy. Clarifying the influencing mechanism of pre-service teachers' digital ethical literacy not only helps to improve the teacher education curriculum system, but also provides empirical support for the promotion of educational equity.

This study takes pre-service teachers in primary and secondary schools in Southwest China as the research object, and adopts a combination of questionnaire survey and logistic regression modeling to systematically analyze the key factors affecting the digital ethical literacy of pre-service teachers. The study first sorts out the variables that may affect digital ethical literacy through interviews, and then designs a questionnaire to examine the digital literacy status of pre-service teachers from four dimensions. On this basis, an ordered multicategorical logistic regression model was constructed to quantitatively analyze the influencing factors. The study not only reveals the differences in the current status of pre-service teachers' digital ethical literacy, but also identifies the importance ranking of the key influencing factors, providing targeted suggestions for the cultivation of pre-service teachers' digital ethical literacy, which is of great significance for promoting educational equity and enhancing the quality of digital education.

II. Research base

II. A. Digital Ethical Literacy

Digital ethical literacy is the cornerstone of a digitally virtuous ethical order. Digital ethical literacy refers to the knowledge and skills necessary to make ethical decisions and act responsibly when using digital technologies.

Digital literacy mainly refers to “a collection of qualities and abilities in digital acquisition, production, use, evaluation, interaction, sharing, innovation, safety and security, ethics and morality that citizens in digital society should possess in their learning and working life”. This definition emphasizes not only the multiple and complex nature of digital literacy, but also the process, social nature and the attributes of competence that reflect these complex features. In other words, digital literacy and skills not only mean that people have knowledge and skills related to digital technologies such as information and communication, but also include literacy in terms of values, ethics, behaviors, and ways of thinking in the digital society [14], [15]. Thus, digital ethical literacy is an important part of digital literacy and skills.

Specifically, digital ethics literacy contains three levels.

The first level is awareness and responsibility for digital ethics, awareness and understanding of ethical issues in the development and application of digital technologies, awareness of the potential consequences of digital technologies for individuals, society, and the environment, and awareness of the ethical implications of decisions made in the development and application of digital technologies.

The second level is digital ethics norm compliance, understanding of relevant digital ethics norms and laws and regulations, and actively practicing and complying with these norms and regulations in practice.

The third level is the ability to think and make decisions in digital ethics, to critically assess ethical issues related to digital technology, to weigh different ethical principles, and to make ethical decisions based on ethical reasoning.

By enhancing digital ethics literacy in these three areas, individuals and organizations can more effectively respond to complex ethical issues in the digital world and make effective and ethical decisions and actions.

II. A. 1) Digital ethics education for pre-service teachers

The purpose of digital ethics education is to improve citizens' digital ethics literacy, which mainly involves digital ethics awareness, digital social responsibility, digital ethics norms, and digital ethics decision-making ability. Only by improving the digital ethical literacy of citizens can it lead to the formation of digital adaptability, competence and creativity and effectively support the construction of digital culture.

Digital social responsibility is the responsibility that individual teachers or groups of teachers need to bear for the digital society as a whole, which consists of role obligation responsibility and legal responsibility. And digital ethics is the normative system of teachers' moral behavior, including teachers' professional moral standards and values. The practice of digital social responsibility helps to enhance teachers' digital ethics. And the compliance of digital ethical norms can guide teachers to make educational behaviors in line with social responsibility, prompting teachers to assume digital social responsibility.

Teachers' digital ethical literacy directly affects and determines the rationality of their digital educational behavior. Digital ethics education for teachers not only helps teachers to get clear moral guidance in the process of digital education and teaching, and correct the digital consciousness of education, but also helps to improve teachers' sense of moral responsibility for the consequences of the application of digital products.

Pre-service teachers belong to the core reserve force of the teaching force, which mainly refers to college and university students whose majors are teacher training and who will be engaged in the teaching profession. According to the Theory of Pedagogical Knowledge of Subjects Integrating Technology (TPACK), the differences between pre-service teachers and in-service teachers are mainly in the areas of technological literacy, subject matter literacy, and pedagogical literacy. Compared with the empirical characteristics of subject knowledge and pedagogical knowledge, the instrumental attribute of technological literacy determines that it has the characteristics of education and training that can be easily mastered by pre-service teachers. And after pre-service teachers are equipped with the basic ability of integrating and innovating information technology and education and teaching, it is more conducive to the formation of the comprehensive ability of TPACK.

II. A. 2) Variable grooming

(1) Determining the methodology

In order to accurately understand the factors influencing the digital ethical literacy of primary and secondary pre-service teachers, six primary and secondary pre-service teachers whose classrooms use intelligent teaching devices in their lessons were selected as the interview subjects to learn about their perceptions, attitudes, and use of digital education. As well as their understanding of digital ethical issues in education in the process of educational practice. Based on the interviews, it is clear that teachers believe that their proficiency in applying digital technology and the digital knowledge they already possess affects the development of their digital ethical literacy.

Since the environment and responsibilities of the work of pre-service teachers in primary and secondary schools are fundamentally different from those used by regular users, pre-service teachers in primary and secondary schools are often confronted with the use of technology by students in the classroom, and teachers are responsible not only for educating each student throughout the classroom and on an individual basis, but also for developing lesson plans, monitoring students' progress, collaborating with other teachers, attending trainings outside of working hours, and ensuring that students are safely applying technology etc.

Several teachers mentioned feelings of stress in their daily teaching due to the use of digital technology. It was found that technological stress negatively affects the health and work performance of individuals, and in severe cases, there is even the intention of job transfer. When technological stress affects the work and life of teachers, they have no time to think about the ethical issues that digital brings to education, and even less time and energy to develop their ethical literacy.

(2) Division of Literacy Dimension

Basic education has a fundamental, overall and pioneering role in education reform and development. Equity in basic education, as the focus of education reform, affects students' learning experience, learning interest and value judgment of fairness or not. Digital teaching is widely and deeply used in the teaching process of primary and secondary schools, and the hardware configuration of technology and the intelligent educational literacy of teachers and students have become important factors in the realization of teaching equity. The key to the application of digital technology in education lies in the configuration of hardware and the support of corresponding technology, which can help teachers realize teaching interactions with digital technology with different degrees of precision and depth. However, education is a human-to-human interaction, and it is difficult to realize educational equity supported by hardware alone. Therefore, the active role of teachers is indispensable in the maintenance and realization of educational equity.

Therefore, whether teachers can utilize digital technology to treat students “equally” becomes the first point of investigation of equity in the process of intelligent education. Therefore, in this study, the maintenance of educational equity refers to the teachers' ability to use digital education to teach according to the specific situation of the students and their own qualifications, targeted education, to ensure that all students can benefit from digital technology.

At the same time, digital teaching in providing students with intelligent teaching services, teachers should allow students to make choices according to their own needs and personality traits, rather than forcing them to make choices. That is to say, throughout the teaching and learning process, fully uphold their own and students' basic human rights and dignity.

II. B. Brief description of the logistic regression model

Logistic regression is a machine learning model [16], [17]. Machine Learning (ML), in layman's terms, is the process of emulating human learning so that computers automatically improve themselves based on experience. It is the process of using algorithms to allow computers to autonomously construct appropriate models with known data and make judgments about new data based on this model. Unlike traditional computers that work passively according to instructions, machine learning is a process in which a machine simulates or implements human learning behaviors through the input of big data, from which it actively seeks laws and verifies them in order to acquire new knowledge or skills. And it can constantly update the existing knowledge structure according to the data to make its performance better or adapt to newer data.

Machine learning belongs to a branch of artificial intelligence, and in many areas of artificial intelligence, it is the core of the existence of the general deserves. Machine learning, it can be said, is the root of artificial intelligence. The scope of application of machine learning has covered all areas of artificial intelligence, and even some industrial processes, machine learning has begun to be introduced to help improve efficiency and increase production capacity. Machine learning for data processing breadth and depth, prediction and learning can be carried out simultaneously. Data learning can be used to build an analysis system that does not rely on explicitly constructed rules and assumptions, which can reduce human investment and achieve better predictive results.

II. B. 1) Requirements analysis and process of logistic regression modeling

Logistic regression model, as a kind of machine learning model, can precisely realize the above needs, and after reasonable training, it can not only classify the existing viruses, but also make certain predictions on the unknown viruses. Moreover, the whole process is easier to realize automated operation, greatly reducing the consumption of manpower and material resources.

Combining the process of network security work and the logistic regression model itself, the designed model flow is shown in Figure 1.

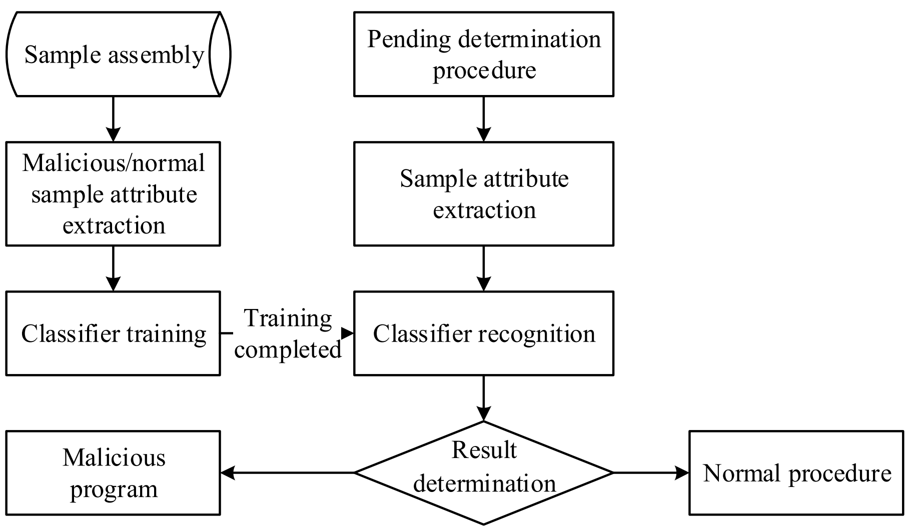

Figure 1: Model flow

II. B. 2) Core Ideas for Building Logistic Regression Models

Logistic regression models are usually binary models, used for binary classification problems. However, it can be generalized to a multinomial logistic regression model for multiple classification. Such models are generally used to estimate the likelihood of something. The result of logistic regression is not a probability value in the mathematical definition. The result is usually used for weighted summation with other eigenvalues rather than direct multiplication.

For the binary classification problem, the decision boundary is denoted by $E_{\Theta}(X)=0$. Then there is a probability that when $E_{\Theta}(X)>0$, the probability that the sample is labeled with a certain type will be greater than 0.5. When $E_{\Theta}(X)<0$, the probability that the sample is labeled with a type of a certain type will be less than 0.5. When $E_{\Theta}(X)$ is approximately equal to 0, the probability that the sample is labeled with a type of a certain type will be around 0.5.

If one wants to know what the probability of a sample label being of a certain type is, this can be achieved with the sigmoid function. This function can be applied to convert the $E_{\Theta}(X)$ function into a probability function in a binary classification problem. When $x=0$, the value of the Sigmoid function is 0.5. As x increases, the corresponding Sigmoid value will be infinitely close to 1. And as x decreases, the Sigmoid value will be infinitely close to 0.

In the binary classification problem, the logistic regression function $h_\Theta(X) = sigmoid(E_\Theta(X))$ can be found, and the judgment boundary can be regarded as the contour at $h_\Theta(X) = 0.5$. The formula is shown below:

$$g(x) = \frac{1}{1-e^{-x}} \tag{1}$$

$$h_\Theta(X) = g(E_\Theta(X)) = g(\Theta^T X) = \frac{1}{1+e^{-\Theta^T X}} \tag{2}$$

Compared with linear regression, logistic regression has a lot in common with linear regression because the variables y in logistic regression follow a Bernoulli distribution and the variables y in linear regression follow a Gaussian distribution. The logistic regression algorithm is a linear regression if the Sigmoid mapping function is removed. It can be said that logistic regression is theoretically supported by linear regression, but logistic regression introduces non-linear factors through the Sigmoid function. Therefore it can easily handle 0/1 categorization problems.

As for the case of multicategorization, suppose the set of values of the category Y is $1,2,....K$, then the multinomial logistic regression model is:

$$P(y=k \mid x) = \frac{\exp(w_k \cdot x)}{1+\sum_{k=1}^{K-1}\exp(w_k \cdot x)} \quad k=1,2,\cdots,K-1 \tag{3}$$

$$P(y=K \mid x) = \frac{1}{1+\sum_{k=1}^{K-1}\exp(w_k \cdot x)} \tag{4}$$

The likelihood function is:

$$\prod_{i=1}^{N}\prod_{k=1}^{K} P(y_i = k \mid x_i)^{y_i^k} \tag{5}$$

where $P(y_i = k \mid x_i)$ is the probability that the model will award the input sample x_i to category k when it is entered, and y_i^k acts as an indicator function. It is 1 when k equals the labeled category of the sample x_i and 0 for the rest.

Taking the logarithm of the likelihood function and then taking the negative, we obtain $L(w_1, w_2, \cdots, w_{K-1})$ (shortened to $L(w)$), which ultimately is to be trained to the model parameters, $w_1, w_2, \cdots, w_{K-1}$, in a way that the value of $L(w))$ takes the smallest value.

II. B. 3) Fundamentals of logistic regression modeling

Logistic regression is essentially a nonlinear model that changes from linear regression, which is a classical statistical model that predicts some continuous numerical variable based on known variables. Its expression is shown below:

$$z = \theta_0 + \theta_1 x_1 + \theta_2 x_2 + ... + \theta_n x_n \tag{6}$$

where θ_0 is the intercept, $\theta_1, \theta_2, ..., \theta_n$ are the partial regression coefficients corresponding to the respective dependent variables.

The above equation requires a monotonically differentiable function to relate the true category y in the variables to the output z in the linear regression model, turning the linear regression equation z into $g(z)$, and such that the output of $g(z)$ is in the range of [0, 1] and is judged to be a positive category when z is greater than zero, negative when z is less than zero, and arbitrarily judged to be equal to zero, i.e., conforming to a unit step function. The calculation formula is:

$$y=\begin{cases}0, z<0;\\0.5, z=0;\\1, z>0,\end{cases} \tag{7}$$

Since the unit step function is non-monotonically differentiable, the Sigmoid function is often used instead of the unit step function. In linear regression $z=\theta_0+\theta_1 x_1+\theta_2 x_2+\ldots+\theta_n x_n$, the general form of the binary logistic regression model is obtained by bringing z into the Sigmoid function, calculated as:

$$g(z)=\frac{1}{1+e^{-(\theta_0+\theta_1 x_1+\theta_2 x_2+\ldots+\theta_n x_n)}}=h_\theta(X) \tag{8}$$

The variables of a binary logistic regression obey a Bernoulli distribution, and assuming that the conditional probabilities of the dependent variable taking the positive and negative categories are denoted by $h_\theta(X)$ and $1-h_\theta(X)$, respectively, when x and θ are known, then the conditional probabilities can be expressed as follows:

$$P_1=P(y=1 \mid X;\theta)=h_\theta(X) \tag{9}$$

$$P_2=P(y=0 \mid X;\theta)=1-h_\theta(X) \tag{10}$$

Integrating the probabilities of the two values of Eq. (9) and Eq. (10) yields the following equation:

$$P(y \mid X;\theta)=P_1^{y}\times P_2^{1-y} \tag{11}$$

In order to solve the unknown parameter θ in the above equation, it is necessary to construct the corresponding likelihood function by the great likelihood estimation method, and then the logarithmic treatment of the likelihood function $L(\theta)$ yields the logarithmic likelihood function $l(\theta)$:

$$l(\theta)=\sum_{i=1}^{n}(y_i\times\log(h_\theta(x_i))+(1-y_i)\times\log(1-h_\theta(x_i))) \tag{12}$$

Multiplying the log-likelihood function $l(\theta)$ by -1, after which the updating process of θ_j can be obtained by gradient descent:

$$\theta_j=\theta_j-\alpha\frac{\partial(-l(\theta))}{\partial\theta_j}(j=1,2,\ldots,p) \tag{13}$$

III. Study design

III. A. Subjects of study

A questionnaire survey method was used with the aim of assessing the digital literacy level of pre-service teachers in primary and secondary schools. The geographical scope of the study was limited to the Southwest region (Yunnan Province, Guizhou Province, Sichuan Province, and Chongqing Municipality).

1524 questionnaires were successfully collected through Questionstar. After excluding invalid samples, 1,466 valid questionnaires were finalized, with a validity rate of 96.19%, making the sample highly representative.

The questionnaires covered a number of basic information about the teachers, including, but not limited to, the teachers' gender, the subject area they taught, the province they were located in, the rank of their title, the number of years of experience, and the region in which they taught.

III. B. Research variables

Drawing mainly on the Teacher Literacy Standards issued by the Ministry of Education and existing studies by relevant scholars, the questionnaire on digital literacy of primary and secondary pre-service teachers in this analysis was designed.

In order to explore in depth the pre-service teachers' cognition, skills, ethical judgment and practical application ability in the digital education environment, the questionnaire covered topics in four parts of pre-service teachers' digital literacy, namely, digital awareness, digital technology, digital ethics, and digital application, in addition to the basic information of the teachers.

In order to ensure the objectivity and accuracy of the evaluation, each question is in the form of a five-point Likert scale, in which the respondents choose the option that best suits their situation from “very much not in line with” to “very much in line with” according to their actual situation. These options correspond to values from 1 to 5.

III. C. Model construction

The explanatory variable “digital ethical literacy of pre-service teachers in primary and secondary schools” is ordered and there are multiple options, and this paper chooses an ordered multicategorical logistic regression model with the following basic form:

$$\ln\left(\frac{p(y \le j \mid x)}{1-p(y \le j \mid x)}\right)=\mu_j-\left(\alpha+\sum_{i=1}^{k}\beta_i x_i\right) \tag{14}$$

$$p(y \le j \mid x)=\frac{e^{\mu_j-\left(\alpha+\sum_{i=1}^{k}\beta_i x_i\right)}}{1+e^{\mu_j-\left(\alpha+\sum_{i=1}^{k}\beta_i x_i\right)}} \tag{15}$$

y is an explanatory variable indicating the degree of digital ethical literacy performance of primary and secondary pre-service teachers. x_i is the influencing factor, indicating the i th factor affecting the digital ethical literacy of primary and secondary pre-service teachers. α is the intercept term, and β is the bias regression coefficient of the logistic regression model, indicating the direction and degree of influence of the influencing factor x_i on y. μ_i is the cut-off point.

IV. The research process

IV. A. Descriptive statistical analysis

This paper is based on descriptive statistical analysis in SPSS 27.0 to test the selected 1466 valid samples. The basic profile of the sample (N=1466) is shown in Table 1.

The statistical results show that in terms of teachers' gender, female teachers accounted for 63.92%, which is higher than male teachers. Among the subjects taught, math teachers accounted for the highest proportion of 38.68%. Among the teaching provinces, Sichuan Province has the most teachers, accounting for 31.17%, followed by Chongqing Municipality.

In terms of target titles, in addition to not knowing their target titles, senior titles were the least, accounting for only 12.89%. In terms of the number of digital ethical literacy trainings, the largest number of teachers with less than 5 times, accounting for 59.69%.

Table 1: The basic case of the sample (n=1466)

Variable	Options	Number	Percentage/%	Variable	Options	Number	Percentage/%
Gender	Man	529	36.08	Target teacher title	Primary	715	48.77
	Female	937	63.92		Intermediate	422	28.79
Teaching discipline	Chinese	429	29.26		Advanced	189	12.89
	Math	567	38.68		Inclarity	140	9.55
	Sports	105	7.16	Training frequency	0-5	875	59.69
	Other	365	24.90		5-10	364	24.83
Teaching province	Chongqing	389	26.53		Above 10	227	15.48
	Sichuan	457	31.17	Teaching area	Countryside	318	21.69
	Yunnan	264	18.01		City	485	33.08
	Guizhou	356	24.28		County	663	45.23

IV. B. Tests of Differences in Different Characterization Groups

The individual difference test of teachers' digital literacy is shown in Table 2.

Mathematics and physical education teachers were the most prominent in digital literacy, while language teachers had relatively low levels of digital literacy, with language teachers' digital literacy level being 3.85 ± 0.96. Teachers in Chongqing Province were ahead of other provinces, especially Guizhou and Yunnan Provinces. The digital ethical literacy of primary and secondary pre-service teachers in Sichuan Province was 3.87±1.24. Pre-service teachers with more than 10 trainings had higher digital literacy, followed by pre-service teachers with 5-10 trainings, and relatively lower by pre-service teachers with less than 5 trainings.

In addition, urban teachers were slightly more digitally literate than county and town teachers, and rural teachers had slightly weaker levels of digital literacy. These differences may be closely related to instructional needs, district resources, professional development, work experience, and educational stage characteristics.

Table 2: Individual differences in teacher digital literacy

Variable	Options	Mean value ±Standard deviation	F	LSD
Teaching discipline	Chinese	3.85 ±0.96	<0.001	Math>Sports> Chinese>Other
	Math	4.21 ±0.61		
	Sports	4.03 ±0.68		
	Other	3.75 ±0.72		
Teaching province	Chongqing	4.02 ±0.78	<0.001	Chongqing>Sichuan> Guizhou>Yunnan
	Sichuan	3.87 ±1.24		
	Yunnan	3.56 ±0.95		
	Guizhou	3.72 ±1.53		
Target teacher title	Primary	4.06 ±0.68	<0.001	Advanced>Intermediate >Primary>Inclarity
	Intermediate	4.12 ±0.52		
	Advanced	4.45 ±0.61		
	Inclarity	3.57 ±1.57		
Training frequency	0-5	3.76 ±1.26	<0.001	Above 10>5-10>0-5
	5-10	4.14 ±0.68		
	Above 10	4.35 ±0.63		
Teaching area	Countryside	3.67 ±1.29	<0.001	City>County> Countryside
	City	4.12 ±0.67		
	County	4.01 ±0.84		

IV. C. Model estimation

IV. C. 1) Selection of parameter values

A Lasso-logistic model was first developed using the dependent variable (digital ethical literacy) and several independent variables. Generalized cross-validation is performed to derive the trend of the values of the reconciliation parameter λ corresponding to the model accuracy.

A larger degree of model compression will make λ larger, the number of remaining variables will be reduced, and some variables will be eliminated resulting in a gradual increase in model error, which is due to the fact that more and more coefficients of the independent variables are compressed to zero, resulting in a loss of information on the original variables.

The change in model accuracy for different values of λ is shown in Figure 2, which shows the results of the cross-validation estimator for the parameter part. As the degree of model compression increases, the model accuracy shows a tendency to first increase and then rapidly decrease to the lowest value, the dashed line corresponds to the highest accuracy achieved by the model in the vertical coordinate, and the horizontal coordinate corresponds to the reconciling parameter λ value, which is called the optimal λ value. It is observed that the best λ values for the lasso model in this paper are found to be around -0.05 to 0.01.

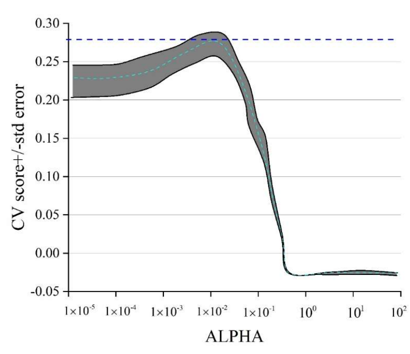

Figure 2: Changes in the model accuracy of different λ values

IV. C. 2) Multicollinearity diagnosis

The influence factors were tested for multicollinearity and the diagnosis of multicollinearity is shown in Table 3. The independent variables include the subject of teaching, province of teaching, target title, number of trainings, and region of teaching as mentioned above, and also include teachers' education level, monthly income, number of students, class structure, and years of professional study. The tolerance is greater than 0.1 and the variance inflation factor is less than 10, indicating that there is no multicollinearity problem among the independent variables.

Table 3: Multiple conlinear diagnosis

Independent variable	Common linear statistics	
	Tolerance	VIF(variance inflation factor)
Education	0.758	1.231
Monthly income	0.625	2.635
Student population	0.311	1.258
Class structure	0.512	6.667
Professional learning years	0.678	1.725
Teaching discipline	0.704	1.263
Teaching province	0.427	3.780
Target teacher title	0.689	1.824
Training frequency	0.513	2.605
Teaching area	0.426	5.568

IV. D. Logistics regression model estimation results

The ordered multicategorical Logistics regression of the influencing factors and explanatory variables was conducted using SPSS27.0 statistical software. The estimated results of the ordered multicategorical Logistics regression model affecting digital ethical literacy of pre-service teachers in primary and secondary schools are shown in Table 4.

From the model fitting effect, the likelihood ratio chi-square statistic was 701.230, corresponding to a sig value of 0.000, which passed the significance test at the 1% level. $Cox\,\&\,Snell\ R^2$ is 0.379 and $Nagelkerke\ R^2$ is 0.355, indicating that the model fits well overall.

The rankings of the factors influencing the digital ethical literacy of pre-service teachers in primary and secondary schools were: education level, years of professional study, target teacher title, subject taught, number of trainings, monthly income, teaching area, teaching province, class structure, and number of students.

Table 4: An ordered multi-class logistics regression model is estimated

Variable name	B	Standard error	Wlad value	P	Exp(B)
Education	-0.675	0.256	0.075	0.758	0.693
Monthly income	-0.403	0.137	0.893	0.224	0.754
Student population	-0.177	0.248	0.662	0.263	0.632
Class structure	-0.193	0.115	0.708	0.546	0.326
Professional learning years	-0.664	0.103	0.214	0.000***	1.005
Teaching discipline	0.501	0.156	0.321	0.124	0.526
Teaching province	-0.196	0.121	0.524	0.362	0.993
Target teacher title	-0.552	1.009	0.366	0.042	0.554
Training frequency	0.484	1.003	2.255	0.121	0.221
Teaching area	-0.263	0.154	0.412	0.426	0.504

V. Conclusion

The study presents the key influencing factors of digital ethical literacy of elementary and secondary pre-service teachers through ordered multicategorical logistic regression model analysis. Teachers' level of education and years of professional study were in the top two places in the ranking of the influencing factors, indicating that education and professional training play a fundamental role in the formation of digital ethical literacy. The target teacher's title and the subject of teaching are important factors influencing digital ethical literacy, in which the digital literacy score of teachers whose target title is senior reaches 4.45, higher than that of teachers with other titles. The number of trainings has a significant effect on digital ethical literacy, with teachers who have received more than 10 trainings significantly higher than those who have received less than 5 trainings, with a difference of 0.59. In addition, the difference in digital literacy caused by the region of teaching should not be ignored, with urban teachers having a digital literacy score of 4.12 and rural teachers having a digital literacy score of 3.67, with a difference of 0.45. These findings suggest that the enhancement of digital ethical literacy of preservice teachers should start from strengthening the quality of higher education and professional learning, and then continue with the improvement of digital ethical literacy in the field. should begin with strengthening the quality of higher education and professional learning, clarifying career paths, increasing training opportunities, and narrowing regional gaps. The development of differentiated training strategies for pre-service teachers in different disciplines and different regions will help promote the overall development of pre-service teachers' digital ethical literacy, which in turn will provide strong support for the healthy development of digital education and educational equity.

Conflict of interest statement

No potential conflict of interest was reported by the author. These authors contributed equally to this work.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Ethics statement

This study was reviewed and approved by Guangxi Normal University. Consent forms were obtained from participants before data collection.

Funding

This work was supported by the Innovation Project of Guangxi Graduate Education "'Collaboration-Integration-Connectivity' of Master of Education Graduate Talent Cultivation Mode" , grant number XJJY2020004, the Innovation Project of Guangxi Graduate Education "Research on Digital Literacy Enhancement Strategies for Primary and Secondary School Teachers in Guangxi", grant number JYCX2023009 and the Guangxi Normal University 2024 The project of Excellent Dissertation Cultivation Program for Postgraduates (Project leader: Min Wang).

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