International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 17 (2025) pp. 1-17

https://doi.org/10.70917/ijcisim-2025-0299
Article

A statistical modeling study of regression analysis in the identification of factors influencing physical education teaching satisfaction

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Abstract: In order to accurately identify the key influencing factors of physical education teaching satisfaction, this study constructed a research model and hypotheses with student satisfaction as the dependent variable, covering multiple dimensions such as curriculum and teacher factors. Data were collected through questionnaires, Pearson correlation calculation method was utilized to screen out variables significantly related to satisfaction, and then a multiple linear regression model was established to solve the parameter estimates using the least squares method, and the t-test and P-value were used as the criteria for judging the significance of the parameters. The results of the study show that the overall satisfaction score of students towards physical education teaching is 3.678, which is moderate to high. Students' gender and grade level do not significantly affect their satisfaction with physical education teaching; however, due to the specialization of physical education majors, there is a significant difference between their satisfaction with "curriculum, teacher factors, practical teaching, teaching management and overall" and that of non-physical education majors ($p<0.05$). Regression analysis showed that the five independent variables of "curriculum, teacher factors, practice teaching, teaching security and teaching management" had a significant effect on the overall satisfaction of physical education teaching.

Keywords: Multiple linear regression model; Least squares method; Pearson's coefficient; Teaching satisfaction; Physical education

1. Introduction

With the deepening of education and teaching reform, various teaching modes have appeared in the classroom, and the reform of education has brought some new reform modes and concepts into our field of vision, and also provided diversified new ideas for the reform of physical education teaching in China [1-3]. According to the requirements of the "new curriculum reform", schools are required to transition from "exam-oriented education" to "quality education", which requires a change in the traditional teaching mode [4]. However, this is often overlooked in current education. Physical education as an aspect of education, also joined the ranks of the reform, in the traditional model of physical education teaching, schools set the same curriculum every year, students in different grades to learn the same content or in the original basis for a little deepening, students learn more and more through physical education classes, in the long run, to a certain extent, inhibit the development of physical education [5-6]. Therefore, this model is no longer suitable for the development of school sports.

Students as the course feelers, through their investigation and understanding, can accurately understand the problems in physical education teaching, so as to develop better improvement measures, and constantly improve the quality of physical education course teaching. In a broad sense, the satisfaction of physical education teaching is the students' overall evaluation of the teacher's behavior, professional ability, teaching methods, classroom content design and other aspects of the teaching process, as well as the subjective feelings of their own learning results [7-9]; in a narrow sense, it is the students' satisfaction with the teaching of physical education classroom, i.e., the evaluation of services provided by physical education majors to achieve the achievement of students' sports skills. Evaluation of the services provided, such as teaching plans, syllabus, the use of field equipment, and the evaluation of teaching effects [10-11]. Therefore, in order to improve the quality of physical education classroom teaching, it is necessary to fully understand the real ideas of students and evaluate the physical education classroom teaching from the perspective of students, so as to provide an important reference basis for improving the quality of physical education teaching.

As an important index for measuring the quality of physical education teaching, physical education satisfaction can not only truly reflect the quality of physical education teaching, but also help to further promote the reform of physical education teaching and the development of sports. Therefore, the study of physical education teaching satisfaction is very necessary. Literature [12] conducted a questionnaire survey to analyze the satisfaction of physical education teaching, which reflects the satisfaction of physical education teaching through four aspects, namely, teaching planning, teaching relationship and environment, teaching effect, results or students' preference. Literature [13] explored the strengths, weaknesses, opportunities and threats in the process of teaching and learning physical education by means of a questionnaire to analyze and combined with based on 7 factors, explored the options to increase the level of satisfaction of students after participating in physical education courses. Literature [14] takes educational satisfaction as a key element in the feedback system provided to students, which greatly contributes to this process, and constructs an educational quality monitoring system, which not only evaluates the effectiveness of the implementation of physical education courses at different levels, but also stimulates the motivation of students to learn, thus promoting the all-around development of students' physical and mental health. Literature [15] examined the relationship between teacher empathy, system quality and reputation on educational satisfaction in physical education programs through structural equation modeling, and found that there is a positive effect between teacher empathy and system quality, while reputation also has a beneficial effect on physical education satisfaction.

Regarding the research on the influencing factors of physical education teaching satisfaction, the literature [16] used 462 physical education teachers and 2,681 students as samples, and analyzed the physical education teaching satisfaction in detail by using structural equation modeling, and found that physical education teachers' self-efficacy is one of the factors affecting the satisfaction of teaching, in which the teachers' self-efficacy can indirectly and positively affect the teaching through the motivation of learning and the learning atmosphere satisfaction. Literature [17] studied 1118 students through structural equation modeling, correlation analysis, and other statistical methods and found that the autonomy and competence that students gained from the physical education classroom positively predicted students' basic psychological needs (BPNs) and novelty satisfaction. Literature [18] explored the effects of two different instructional models, blended learning in physical education (BLI) and traditional physical education classroom (CLI), on satisfaction with physical education and found that the BLI model made them more interested in the content of the physical education course, increased their satisfaction with their learning, and also indirectly enhanced their learning outcomes. Literature [19] explored the relationship between responsibility assignment, motivational variables and satisfaction with physical education teaching using the Student Responsibility Scale, the Basic Psychological Needs Measurement Scale, the Percentage of Physical Education Causality Scale, and the Physical Education Satisfaction Scale as measurement tools. Literature [20] explored the effects of different dimensions on satisfaction with physical education teaching through multiple linear regression models, specifically including four dimensions of teacher quality, course content, teaching organization, and facility infrastructure, and found that all four dimensions had a significant positive effect on satisfaction with physical education teaching.

In summary, although scholars have been conducting multi-faceted and multi-faceted research on the direction of physical education teaching satisfaction, and have made positive progress, which has far-reaching impacts on both theory and practice, from the research results, the authoritative and generally recognized and adopted education satisfaction measurement system is always absent in the current physical education system in China, and so there is no consistency in the conclusions of the research shown. Some studies point out that the teaching content is the key point that affects the satisfaction of physical education teaching, some think that the conditions of school running should not be ignored, and some suggest that the best way to improve the satisfaction is to derive rich extracurricular activities. The selection of satisfaction indexes is also relatively scattered, and there is no uniform standard whether focusing on students' subjective feelings or objective indexes.

In this paper, we first constructed a model for analyzing the satisfaction of physical education teaching, and put forward the model hypotheses involving five aspects: curriculum, teacher factors, practical teaching, teaching guarantee and teaching management. The data of different influencing factors on students' satisfaction with physical education teaching were obtained through questionnaire survey method, and the relationship between the influencing factors was analyzed using Pearson correlation calculation method. After that, a multiple linear regression model with physical education teaching satisfaction as the dependent variable was constructed, the parameter estimates of the model were solved by the least squares method, and then the correlation analysis was conducted by using the t-test and the P-value as the judgment criteria for the significance of the parameters, and finally the corresponding countermeasures were put forward according to the results of the analysis.

2. Statistical model of physical education teaching satisfaction based on regression analysis

2.1. Analysis model construction of physical education teaching satisfaction

2.1.1. Research models and hypotheses

Whether students are satisfied with physical education teaching affects the effectiveness of physical education teaching in colleges and universities. Based on this, this study proposes five dimensions affecting the satisfaction of physical education teaching-curriculum, teacher factors, practical teaching, teaching guarantee and teaching management. And these five dimensions together form the independent variable of physical education teaching satisfaction.

Previous researchers have discussed the influencing factors of students' satisfaction with physical education teaching from the perspectives of “curriculum, teacher factors, practice teaching, teaching security and teaching management”, and concluded that they have a positive indirect effect on the satisfaction with physical education teaching. Therefore, this paper hypothesizes that

H1: Curriculum has a positive effect on the satisfaction of physical education teaching;

H2: Teacher factors have a positive effect on satisfaction with physical education teaching;

H3: Practical teaching has a positive effect on physical education teaching satisfaction;

H4: Teaching security has a positive effect on satisfaction with physical education teaching;

H5: Teaching management has a positive effect on satisfaction with physical education teaching.

2.1.2. Research design

(1) Data collection and sample description

This study takes college students in City A as the survey object and collects data by randomly distributing questionnaires online. A total of 300 questionnaires were distributed and 296 were recovered, with 284 valid questionnaires and an effective recovery rate of 94.67%. Male students accounted for 55.28% (157) and female students accounted for 44.72% (127) of the 284 samples; freshmen and sophomores accounted for a total of 166 people, juniors accounted for 85 people, and senior and other grades accounted for a total of 33 people. It can be seen that the respondents covered different genders and grades, and the questionnaire was representative.

(2) Questionnaire and Scale

The questionnaire consisted of two parts, the first part was the demographic characteristics of the sample, including the indicators of gender and grade level, and the second part was the indicators of the independent and dependent variables related to satisfaction with physical education teaching using a five-point Likert scale. Assign values to all variables in ascending order: 1 indicates "very dissatisfied"; 2 means "dissatisfied"; 3 means "average"; 4 means "satisfied"; 5 means "very satisfied". After calculation, the reliability and validity of the questionnaire were 0.8624 and 0.8851 respectively, and the design of the scale was reasonable.

2.2. Pearson correlation calculation method

Define the aggregate of two-dimensional variables X,Y as $(X,Y)^T$, $(x_1,y_1)^T,(x_2,y_2)^T,\cdots,(x_n,y_n)^T$ are the experimental samples of the variables, which are also observations, yielding the observation matrix M:

$$M=\begin{bmatrix} x_1 & x_2 & \cdots & x_n \\ y_1 & y_2 & \cdots & y_n \end{bmatrix}^T \tag{1}$$

Calculate the mean of the variable X and the variable Y separately:

$$\bar{x}=\frac{1}{n}\sum_{i=1}^{n}x_i \tag{2}$$

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i \tag{3}$$

Equation (2) represents the mean of the observed data for variable X and equation (3) is the mean of the observed data for variable Y. The data variance is further calculated:

$$S_{xx} = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2 \tag{4}$$

$$S_{yy} = \frac{1}{n-1}\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2 \tag{5}$$

$$S_{xy} = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right) \tag{6}$$

The above equation calculates the covariance of the observed data for the variable X, the variable Y, and the two-dimensional variable $\left(X, Y\right)$, respectively, and defines S as the covariance matrix of the observed data, then:

$$S = \begin{bmatrix} S_{xx} & S_{xy} \\ S_{yx} & S_{yy} \end{bmatrix} \tag{7}$$

In matrix S, there is $S_{xy} = S_{yx}$, so the diagonal elements are equal and it is a symmetric matrix. Moreover, according to Schwarz's inequality, there is:

$$S_{xy}^2 \le S_{xx} S_{yy} \tag{8}$$

Thus the matrix S is positive definite. The correlation coefficient of the observations defining X, Y is given by:

$$r_{xy} = \frac{S_{xy}}{\sqrt{S_{xx}}\sqrt{S_{yy}}} \tag{9}$$

According to Schwarz's inequality, $\left|r_{xy}\right| \le 1$ holds. r_{xy} is used to measure the degree of linear correlation of variable X, Y. Let the overall of two-dimensional variable $\left(X, Y\right)$ be $\left(X, Y\right)^T$, then the correlation coefficient of $\left(X, Y\right)$ is calculated as:

$$r_{XY} = \frac{Cov\left(X, Y\right)}{\sqrt{Var\left(X\right)}\sqrt{Var\left(Y\right)}} \tag{10}$$

Where $Var(X)$, $Var(Y)$ are the variance of variable X and variable Y respectively, and $Cov\left(X, Y\right)$ is the covariance of the two-dimensional total $\left(X, Y\right)$. The Pearson correlation coefficient takes the range of $r \in \left[-1, 1\right]$, and it is usually used to determine the strength of correlation between two variables. The absolute value of Pearson's coefficient is used to determine the strength of the correlation between two variables, and the rules are as follows: $r > 0$ means positive correlation, $r < 0$ means negative correlation; $\left|r\right| = 0$ means there is no linear relationship; $\left|r\right| = 1$ means complete linear correlation.

In short, the absolute value of the Pearson coefficient is close to 1, which proves that the correlation between the two variables is stronger; on the contrary, the smaller the absolute value is, the weaker the correlation between the variables is, and the stronger the independence is. Meanwhile, it should be noted that the use of Pearson's correlation coefficient needs to follow the following principles:

①Pearson's correlation coefficient is only applicable to the analysis of linearly correlated data;

②The calculation of the Pearson coefficient has a large impact when there are extreme values in the observed data of the variable;

③The use of Pearson's correlation coefficient requires that the two-dimensional totals (X,Y) under test obey a bivariate normal distribution.

2.3. Multiple regression modeling

2.3.1. Multiple linear regression models

The multiple linear regression model [21] is interpreted as having a linear relationship between the variable Y and multiple explanatory variables $X_1, X_2, \cdots, X_k$. The assumption that there is a linear relationship between the explained variable Y and multiple explanatory variables $X_1, X_2, \cdots, X_k$ is a multivariate linear function of the explanatory variables and is known as a multivariate linear regression model. To wit:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \mu \tag{11}$$

where Y is the explanatory variable (dependent variable), $X_j\left(j=1,2,\cdots,k\right)$ is the k explanatory variables (independent variables), and $\beta_j\left(j=0,1,2,\cdots,k\right)$ is the $k+1$ unknown parameter, the regression coefficient, and μ is the random error, also known as the residual, which is usually assumed to be $\mu \sim N\left(0,\sigma^2\right)$.

The linear equation between the expected value of the explanatory variable Y and the explanatory variables $X_1, X_2, \cdots, X_k$ is:

$$E(Y) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k \tag{12}$$

It is called the multivariate overall linear regression equation, or overall regression equation for short.

For n sets of observations $Y_i, X_{1i}, X_{2i}, \cdots, X_{ki}\left(i=1,2,\cdots,n\right)$, the system of equations takes the form:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + \mu_i, \left(i=1,2,\cdots,n\right) \tag{13}$$

To wit:

$$\begin{cases} Y_1 = \beta_0 + \beta_1 X_{11} + \beta_2 X_{21} + \cdots + \beta_k X_{k1} + \mu_1 \\ Y_2 = \beta_0 + \beta_1 X_{12} + \beta_2 X_{22} + \cdots + \beta_k X_{k2} + \mu_2 \\ \cdots\cdots \\ Y_n = \beta_0 + \beta_1 X_{1n} + \beta_2 X_{2n} + \cdots + \beta_k X_{kn} + \mu_n \end{cases} \tag{14}$$

Its matrix form is:

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} = \begin{bmatrix} 1 & X_{11} & X_{21} & \cdots & X_{k1} \\ 1 & X_{12} & X_{22} & \cdots & X_{k2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & X_{1n} & X_{2n} & \cdots & X_{kn} \end{bmatrix} \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \vdots \\ \beta_k \end{bmatrix} + \begin{bmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_n \end{bmatrix} \tag{15}$$

To wit:

$$Y = X\beta + \mu \tag{16}$$

Among them:

$Y_{n\times 1}=\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix}$ is a vector of observations of the explanatory variables;

$X_{n\times(k+1)}=\begin{bmatrix} 1 & X_{11} & X_{21} & \cdots & X_{k1} \\ 1 & X_{12} & X_{22} & \cdots & X_{k2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & X_{1n} & X_{2n} & \cdots & X_{kn} \end{bmatrix}$ is the matrix of observations of the explanatory variables;

$\beta_{(k+1)\times 1}=\begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \vdots \\ \beta_k \end{bmatrix}$ is the vector of the overall regression parameters; $\mu_{n\times 1}=\begin{bmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_n \end{bmatrix}$ is the vector of random error terms.

The overall regression equation is expressed as:

$$E\left(Y\right)=X\beta \tag{17}$$

Multiple linear regression analysis is used to estimate each parameter in the model based on the observed samples, and the estimated parameters and regression equations are statistically tested so that the regression model can be used for size prediction and analysis.

Since the parameters $\beta_0,\beta_1,\beta_2,\cdots,\beta_k$ are unknown, they can be estimated using the sample observations $\left(X_{1i},X_{2i},\cdots,X_{ki};Y_i\right)$. If the calculated parameter estimates are $\hat{\beta}_0,\hat{\beta}_1,\hat{\beta}_2,\cdots,\hat{\beta}_k$, and the parameter estimates are used to replace the unknown parameters of the overall regression function $\beta_0,\beta_1,\beta_2,\cdots,\beta_k$, the multivariate linear sample regression equation is obtained:

$$\hat{Y}_i=\hat{\beta}_0+\hat{\beta}_1X_{1i}+\hat{\beta}_2X_{2i}+\cdots+\hat{\beta}_kX_{ki} \tag{18}$$

Where $\hat{\beta}_j\left(j=0,1,2,\cdots,k\right)$ is the parameter estimator, and $\hat{Y}_i\left(i=1,2,\cdots,n\right)$ is the sample regression value or the sample fit, the sample estimator for Y_i.

Its matrix expression form is:

$$\hat{Y}=X\hat{\beta} \tag{19}$$

where $\hat{Y}_{n\times 1}=\begin{bmatrix} \hat{Y}_1 \\ \hat{Y}_2 \\ \vdots \\ \hat{Y}_n \end{bmatrix}$ is the $n\times 1$ th order fit of the vector of sample observations of the explanatory variables Y. value column vector;

$X_{n\times(k+1)}=\begin{bmatrix} 1 & X_{11} & X_{21} & \cdots & X_{k1} \\ 1 & X_{12} & X_{22} & \cdots & X_{k2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & X_{1n} & X_{2n} & \cdots & X_{kn} \end{bmatrix}$ is the $n\times(k+1)$ -order sample observation matrix for the explanatory variable X ;

$$\widehat{\beta}_{(k+1)\times 1}=\begin{bmatrix}\hat{\beta}_0\\ \hat{\beta}_1\\ \hat{\beta}_2\\ \vdots\\ \hat{\beta}_k\end{bmatrix}$$ is a column vector of $\left(k+1\right)\times 1$ th order estimates of the unknown parameter vector β.

The deviation between the estimates of the explanatory variables $\hat{Y}_i$ obtained from the sample regression equation and the actual observations Y_i is called the residuals e_i:

$$e_i=Y_i-\hat{Y}_i=Y_i-\left(\hat{\beta}_0+\hat{\beta}_1X_{1i}+\hat{\beta}_{2i}+\cdots+\hat{\beta}_{ki}X_{ki}\right) \tag{20}$$

2.3.2. Least squares method for solving parameter estimates

The following assumptions must be met when the multiple linear regression model utilizes ordinary least squares [22] (OLS) for parameter estimation:

Assumption 1 Zero mean assumption: $E(\mu_i)=0,i=1,2,\cdots,n$, i.e.:

$$E(\mu)=E\begin{bmatrix}\mu_1\\ \mu_2\\ \vdots\\ \mu_n\end{bmatrix}=\begin{bmatrix}E(\mu_1)\\ E(\mu_2)\\ \vdots\\ E(\mu_n)\end{bmatrix}=0 \tag{21}$$

Assumption 2 Homoscedasticity assumption (the variance of μ is the same constant):

$$Var(\mu_i)=E(\mu_i^2)=\sigma^2,(i=1,2,\cdots,n) \tag{22}$$

Assumption 3 No autocorrelation:

$$Cov(\mu_i,\mu_j)=E(\mu_i\mu_j)=0,(i\neq j,i,j=1,2,\cdots,n) \tag{23}$$

$$\begin{aligned}E(\mu\mu')&=E\begin{bmatrix}\mu_1\\ \mu_2\\ \vdots\\ \mu_n\end{bmatrix}(\mu_1,\mu_2,\cdots,\mu_n)=E\begin{bmatrix}\mu_1^2 & \mu_1\mu_2 & \cdots & \mu_1\mu_n\\ \mu_2\mu_1 & \mu_2^2 & \cdots & \mu_2\mu_n\\ \vdots & \vdots & \vdots & \vdots\\ \mu_n\mu_1 & \mu_n\mu_2 & \cdots & \mu_n^2\end{bmatrix}\\ &=\begin{bmatrix}E(\mu_1^2) & E(\mu_1\mu_2) & \cdots & E(\mu_1\mu_n)\\ E(\mu_2\mu_1) & E(\mu_2^2) & \cdots & E(\mu_2\mu_n)\\ \vdots & \vdots & \vdots & \vdots\\ E(\mu_n\mu_1) & E(\mu_n\mu_2) & \cdots & E(\mu_n^2)\end{bmatrix}\\ &=\begin{bmatrix}\sigma_\mu^2 & 0 & \cdots & 0\\ 0 & \sigma_\mu^2 & \cdots & 0\\ \vdots & \vdots & \vdots & \vdots\\ 0 & 0 & \cdots & \sigma_\mu^2\end{bmatrix}=\sigma_\mu^2 I_n\end{aligned} \tag{24}$$

Assumption 4 The random error term μ is uncorrelated with the explanatory variable X (this assumption holds automatically):

$$Cov\left(X_{ji},\mu_i\right)=0,\left(j=1,2,\cdots,k,i=1,2,\cdots,n\right) \tag{25}$$

Assume that the 5 random error term μ follows a normal distribution with mean zero and variance σ^2:

$$\mu_i \sim N\left(0, \sigma_\mu^2 I_n\right) \tag{26}$$

Assumption 6 There is no multicollinearity between the explanatory variables:

$$rank\left(X\right) = k+1 \le n \tag{27}$$

That is, the sample observations of each explanatory variable are linearly independent of each other, and the rank of the matrix of sample observations of the explanatory variables X is the number of parameters $k+1$, which ensures that the estimates of the parameters $\beta_0, \beta_1, \beta_2, \cdots, \beta_k$ are unique.

For a multiple linear regression model containing k explanatory variables:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + \mu_i \left(i = 1, 2, \cdots, n\right) \tag{28}$$

Setting $\hat{\beta}_0, \hat{\beta}_1, \cdots, \hat{\beta}_k$ as the estimators of the parameters $\beta_0, \beta_1, \cdots, \beta_k$, respectively, yields the sample regression equation:

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 X_{1i} + \hat{\beta}_2 X_{2i} + \cdots + \hat{\beta}_k X_{ki} \tag{29}$$

The residuals e_i of the observation Y_i and the regression $\hat{Y}_i$ are:

$$e_i = Y_i - \hat{Y}_i = Y_i - \left(\hat{\beta}_0 + \hat{\beta}_1 X_{1i} + \hat{\beta}_{2i} + \cdots + \hat{\beta}_{ki} X_{ki}\right) \tag{30}$$

By least squares $\hat{\beta}_0, \hat{\beta}_1, \cdots, \hat{\beta}_k$ should minimize the sum of the squares of the residuals e_i of all the observations Y_i and the regression values $\hat{Y}_i$ even though:

$$\begin{aligned} Q\left(\hat{\beta}_0, \hat{\beta}_1, \hat{\beta}_2, \cdots, \hat{\beta}_k\right) &= \sum e_i^2 = \sum \left(Y_i - \hat{Y}_i\right)^2 \\ &= \sum \left(Y_i - \hat{\beta}_0 - \hat{\beta}_1 X_{1i} - \hat{\beta}_2 X_{2i} - \cdots - \hat{\beta}_k X_{ki}\right)^2 \end{aligned} \tag{31}$$

Obtain the minimum value. According to the principle of extremum of multivariate functions, Q takes the first order partial derivatives of $\hat{\beta}_0, \hat{\beta}_1, \cdots, \hat{\beta}_k$, respectively, and makes them equal to zero, denoted as:

$$\frac{\partial Q}{\partial \hat{\beta}_j} = 0, (j = 1, 2, \cdots, k) \tag{32}$$

Unfolding as:

$$\begin{cases} \dfrac{\partial Q}{\partial \hat{\beta}_0} = 2\sum \left(Y_i - \hat{\beta}_0 - \hat{\beta}_1 X_{1i} - \hat{\beta}_2 X_{2i} - \cdots - \hat{\beta}_k X_{ki}\right)\left(-1\right) = 0 \\ \dfrac{\partial Q}{\partial \hat{\beta}_1} = 2\sum \left(Y_i - \hat{\beta}_0 - \hat{\beta}_1 X_{1i} - \hat{\beta}_2 X_{2i} - \cdots - \hat{\beta}_k X_{ki}\right)\left(-X_{1i}\right) = 0 \\ \cdots\cdots \\ \dfrac{\partial Q}{\partial \hat{\beta}_k} = \sum \left(Y_i - \hat{\beta}_0 - \hat{\beta}_1 X_{1i} - \hat{\beta}_2 X_{2i} - \cdots - \hat{\beta}_k X_{ki}\right)\left(-X_{ki}\right) = 0 \end{cases} \tag{33}$$

Simplify to obtain the following system of equations:

$$\begin{cases} n\hat{\beta}_0 + \hat{\beta}_1 \sum X_{1i} + \hat{\beta}_2 \sum X_{2i} + \cdots + \hat{\beta}_k \sum X_{ki} = \sum Y_i \\ \hat{\beta}_0 \sum X_{1i} + \hat{\beta}_1 \sum X_{1i}^2 + \hat{\beta}_2 \sum X_{2i} X_{1i} + \cdots + \hat{\beta}_k \sum X_{ki} X_{1i} = \sum X_{1i} Y_i \\ \cdots\cdots \\ \hat{\beta}_0 \sum X_{ki} + \hat{\beta}_1 \sum X_{1i} X_{ki} + \hat{\beta}_2 \sum X_{2i} X_{ki} + \cdots + \hat{\beta}_k \sum X_{ki}^2 = \sum X_{ki} Y_i \end{cases} \tag{34}$$

The above $(k+1)$ equations are called regular equations and have the matrix form:

$$\begin{bmatrix} n & \sum X_{1i} & \sum X_{2i} & \cdots & \sum X_{ki} \\ \sum X_{1i} & \sum X_{1i}^2 & \sum X_{2i} X_{1i} & \cdots & \sum X_{ki} X_{1i} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \sum X_{ki} & \sum X_{1i} X_{ki} & \sum X_{2i} X_{ki} & \cdots & \sum X_{ki}^2 \end{bmatrix} \begin{bmatrix} \hat{\beta}_0 \\ \hat{\beta}_1 \\ \hat{\beta}_2 \\ \vdots \\ \hat{\beta}_k \end{bmatrix} = \begin{bmatrix} \sum Y_i \\ \sum X_{1i} Y_i \\ \vdots \\ \sum X_{ki} Y_i \end{bmatrix} \tag{35}$$

Because:

$$\begin{bmatrix} n & \sum X_{1i} & \sum X_{2i} & \cdots & \sum X_{ki} \\ \sum X_{1i} & \sum X_{1i}^2 & \sum X_{2i} X_{1i} & \cdots & \sum X_{ki} X_{1i} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \sum X_{ki} & \sum X_{1i} X_{ki} & \sum X_{2i} X_{ki} & \cdots & \sum X_{ki}^2 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 1 & \cdots & 1 \\ X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ X_{k1} & X_{k2} & \cdots & X_{kn} \end{bmatrix} \begin{bmatrix} 1 & X_{11} & X_{21} & \cdots & X_{k1} \\ 1 & X_{12} & X_{22} & \cdots & X_{k2} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & X_{1n} & X_{2n} & \cdots & X_{kn} \end{bmatrix} = X'X \tag{36}$$

$$\begin{bmatrix} \sum Y_i \\ \sum X_{1i} Y_i \\ \vdots \\ \sum X_{ki} Y_i \end{bmatrix} = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ X_{k1} & X_{k2} & \cdots & X_{kn} \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix} = X'Y$$

Let $\widehat{\beta} = \begin{bmatrix} \hat{\beta}_0 \\ \hat{\beta}_1 \\ \hat{\beta}_2 \\ \vdots \\ \hat{\beta}_k \end{bmatrix}$ be the transpose matrix X' of the vector of estimates sample regression model $Y = X\widehat{\beta} + e$ multiplied by both sides of the matrix of sample observations X, then we have:

$$X'Y = X'X\widehat{\beta} + X'e \tag{37}$$

to obtain a regular system of equations:

$$X'Y = X'X\widehat{\beta} \tag{38}$$

By Assumption 6, $R(X) = k+1$, and $X'X$ is a square matrix of order $(k+1)$, so that $X'X$ is full rank, and the inverse matrix of $X'X$ $\left(X'X\right)^{-1}$ exists. Thus:

$$\widehat{\beta}=\left(X'X\right)^{-1}X'Y \tag{39}$$

is the OLS estimator of the vector β.

2.3.3. Criteria for parameters

The process of establishing the regression equation is the process of estimating the parameters in the regression model. At the same time, the advantages and disadvantages of multiple linear regression modeling have some statistical criteria that facilitate the testing of the validity of the model. These criteria are four as follows:

(1) Coefficient of determination R^2 : i.e., the ratio of the regression squared to the sum of the squares of the total deviations from the mean. Can be used to quantitatively evaluate the proportion of the total variation in Y that can be explained by a linear regression equation built from n X variables. Valid models generally require $R^2 \geq 0.75$.

(2) Residual standard deviation S : can be used to quantitatively evaluate the estimation error generated by the regression equation. Valid models generally require $S \leq 0.05$.

(3) Test for covariance: assesses the independence of the samples. Valid models generally require that the degree of covariance between samples is less than 10.

(4) Extreme sample test: Calculate the residual RStudent of each sample studentized, that is, the standardized error of the sample obtained by removing a sample. This test is used to rate the presence of extreme samples in the sample. Valid models generally require $\left|RStudent\right| \leq 2.5$.

3. Analysis of the results of the identification of factors affecting satisfaction based on physical education teaching

3.1. Analysis of Physical Education Teaching Satisfaction

3.1.1. Normality test of measurement data

The histogram and normal curve of overall student satisfaction are shown in Figure 1. The results show that the raw data of overall student satisfaction is more consistent with the normal distribution curve and can be further analyzed.

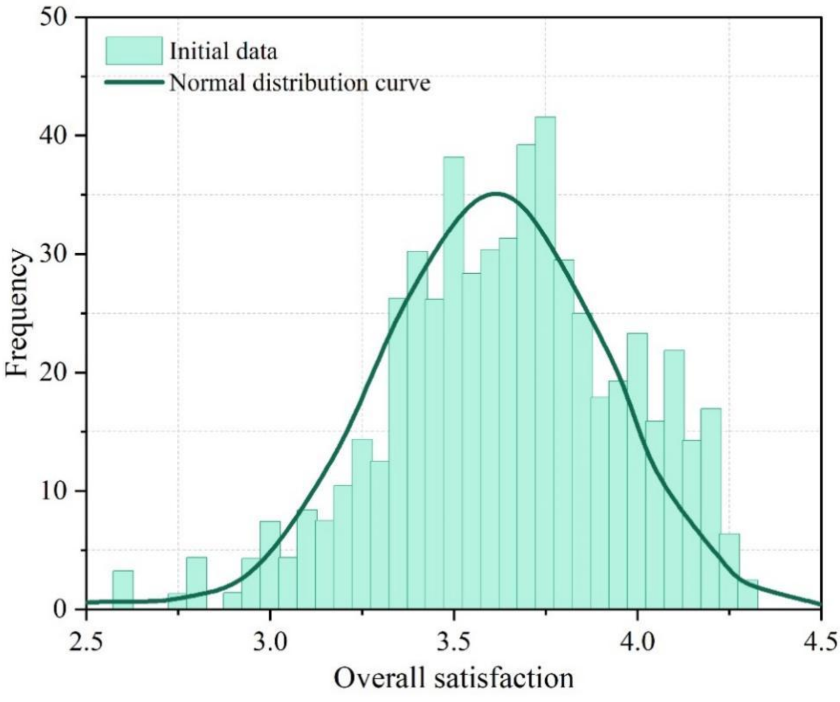

Figure 1. Histogram of student satisfaction versus normal distribution.

3.1.2. Overall profile of satisfaction with teaching and learning

The satisfaction of students with physical education teaching in colleges and universities is shown in Table 1. It can be seen that the overall satisfaction score of students with physical education teaching is 3.678 points. The scores for the five dimensions of "curriculum setting, teacher factors, practical teaching, teaching guarantee and teaching management" are 3.893, 3.743, 4.049, 3.406 and 3.639 respectively. The satisfaction scores for each dimension of physical education teaching from high to low are as follows: Practical Teaching > Curriculum Design > Teacher Factors > Teaching Management > Teacher Support.

In summary, the level of satisfaction with physical education is high, the dimensions of physical education compared with the overall satisfaction with classroom teaching, practical teaching, curriculum and teacher factors are much higher than the overall level of satisfaction, teaching management and physical education teaching overall satisfaction scores are equal, and in the teacher protection is slightly lower than the overall level of satisfaction. With the students in the sports classroom in the continuous improvement of the status of the main body, students for knowledge, social adaptation continues to improve, in promoting the effective unity of the teacher's teaching and student learning at the same time, it is more important to students' ability to interest as the main core, create more suitable for the students to learn, as a way to promote the maximization of student learning.

Table 1. Student satisfaction with physical education in colleges and universities.

Class	Degree of satisfaction	Standard error
Ensemble	3.678	0.328
Course offered	3.893	0.436
Teacher factors	3.743	0.461
Practical teaching	4.049	0.407
Teaching Support	3.406	0.374
Teaching management	3.639	0.359

3.1.3. Analysis of differences in satisfaction with physical education by gender

In order to clarify the influence of students of different genders on the satisfaction of physical education teaching, the study conducted a survey on the satisfaction of physical education teaching of students of different genders (157 male students and 127 female students). The statistical results of the differences between students of different genders on the dimensions of physical education teaching are shown in Table 2. Since there are only two categories between the data, independent samples t-tests were conducted on the relevant data, and the results all showed $P>0.05$, indicating that there is no significant difference between male and female students' satisfaction with physical education teaching in terms of curriculum, teacher factors, practical teaching, teaching guarantee and teaching management, and overall satisfaction. This also indicates that teachers are not biased towards boys and girls in the whole practice of physical education teaching, which does not cause differences in gender.

Table 2. Statistical results of gender satisfaction with physical education.

Class	Sex	Degree of satisfaction	Standard error
Ensemble	Male	3.642	0.407
	Female	3.654	0.539
Course offered	Male	3.845	0.475
	Female	3.877	0.498
Teacher factors	Male	3.744	0.225
	Female	3.767	0.564
Practical teaching	Male	4.116	0.352
	Female	4.091	0.292
Teaching Support	Male	3.443	0.441

	Female	3.472	0.445
Teaching management	Male	3.635	0.418
	Female	3.619	0.282

3.1.4. Differential Analysis of Grade Level Satisfaction with Physical Education Instruction

In order to deeply explore the influence of students' grade level on the satisfaction of physical education teaching, based on the fieldwork, it is understood that physical education teaching is mainly concentrated in freshman and sophomore years. The difference analysis of grade level on satisfaction with physical education teaching is shown in Table 3. The study conducted a survey on students' satisfaction with physical education teaching in different grades (93 students in freshman and 73 students in sophomore), and since the comparative analysis of two different grades was conducted, an independent samples t-test was performed on the relevant data, and the results showed that P>0.05. It can be found that there is no significant difference between freshman and sophomore students in all dimensions and the overall scale, and it also indicates that throughout the practice of physical education teaching, the teachers are treating students of all grades equally.

Table 3. Analysis of grade differences in satisfaction with physical education.

Class	Grade	Degree of satisfaction	Standard error
Ensemble	Freshman	3.619	0.381
	Sophomore	3.634	0.421
Course offered	Freshman	3.846	0.425
	Sophomore	3.876	0.404
Teacher factors	Freshman	3.735	0.185
	Sophomore	3.747	0.628
Practical teaching	Freshman	4.113	0.212
	Sophomore	4.108	0.258
Teaching Support	Freshman	3.427	0.503
	Sophomore	3.415	0.444
Teaching management	Freshman	3.674	0.536
	Sophomore	3.658	0.317

3.1.5. Analysis of Differences in Professional Satisfaction with Physical Education Instruction

In order to clarify the influence of students' satisfaction with physical education teaching in different majors, this study, for the variable of students' majors, mainly including physical education majors (93) and non-physical education majors (191), examines students' satisfaction with physical education teaching in different majors. Since the comparative analysis of two different majors was conducted, the independent samples t-test was performed on the relevant data, and the results showed that P was less than 0.05.

The differences in satisfaction with physical education teaching among different majors are shown in Table 4, and * indicates that P<0.05. It can be found that the satisfaction of physical education majors with physical education teaching in the areas of "curriculum, teacher factors, practical teaching, teaching guarantee and teaching management" is higher than that of non-physical education majors, and the satisfaction of physical education majors with physical education teaching is higher than that of non-physical education majors. There is a significant difference between the satisfaction of "curriculum, teacher factors, practice teaching, teaching management and overall" of physical education majors and that of non-physical education majors (p<0.05). The reason for this result may be due to the specialization of the subjects studied by the students majoring in physical education, the higher requirements of physical education teachers for students majoring in physical education, the more compact teaching guarantee, and the more professional teaching environment. On the other hand, the satisfaction ratings of all students on teaching guarantee were basically similar and none of them had significant differences.

Table 4. Differences in satisfaction with physical education in different majors.

Class	Specialization	Degree of satisfaction	Standard error
Ensemble*	Sports specialty	4.126	0.428
	Non-PE major	3.677	0.485
Course offered*	Sports specialty	3.736	0.228
	Non-PE major	3.428	0.399
Teacher factors*	Sports specialty	4.383	0.141
	Non-PE major	4.048	0.578
Practical teaching*	Sports specialty	3.824	0.267
	Non-PE major	2.664	0.178
Teaching Support	Sports specialty	3.649	0.546
	Non-PE major	3.616	0.362
Teaching management*	Sports specialty	3.674	0.536
	Non-PE major	3.658	0.317

3.2. Correlation Analysis of Factors Influencing Satisfaction with Physical Education Teaching

3.2.1. Correlation analysis

Through the reliability test of the satisfaction scale of physical education teaching in the previous section, the structure of the questionnaire is initially shown to be scientific, and the recovered data are analyzed on the basis of the correlation analysis.

The correlation between satisfaction with physical education teaching and the five variables of "curriculum, teacher factors, practical teaching, teaching security and teaching management" is analyzed by Pearson's coefficient. A correlation coefficient greater than 0.7 is a strong correlation, 0.3 to 0.7 is a moderate correlation, and less than 0.3 is a weak correlation.

The results of the correlation analysis between the factors affecting student satisfaction are shown in Figure 2. By analyzing the correlation coefficients between each index of the questionnaire and the scale as a whole, it can be seen that the correlation coefficients of students' satisfaction with physical education teaching as a whole and the subscales are in the range of [0.514,0.748], and the correlation coefficients all show significance at the level of confidence of 0.01, so it means that the overall satisfaction of students' satisfaction with physical education teaching is related to the following factors: "Curriculum, Teachers, Practical Teaching, Teaching Guarantee, Teaching and Learning". Therefore, it shows that there is a moderate positive correlation between students' overall satisfaction with physical education teaching and the five items of "curriculum, teachers, practical teaching, teaching security and teaching management", and the correlation relationship is relatively strong.

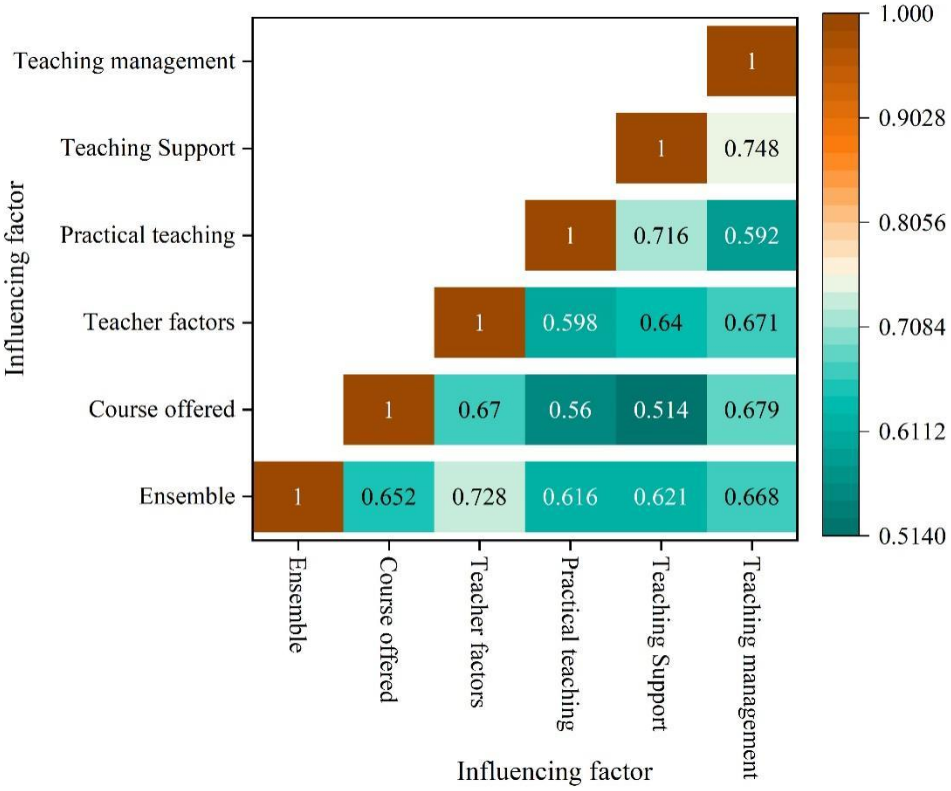

Figure 2. Correlation between factors affecting student satisfaction.

3.2.2. Multiple linear regression analysis

However, correlation analysis has certain limitations in that it can only describe the degree of association between two types of variables and cannot pinpoint the causal relationship in the associated variables. Therefore, regression analysis is needed to explain the statistically significant relationship between the independent variables and the dependent variables and to make up for the inherent shortcomings of correlation analysis. Here, the relationship between overall satisfaction with teaching and the dimensions of the factors influencing satisfaction with teaching is mainly explored using regression analysis. The factors affecting the satisfaction of physical education teaching are taken as independent variables (including the five dimensions of curriculum, teacher factors, practice teaching, teaching guarantee, and teaching management), and the overall satisfaction of physical education teaching is regressed as the dependent variable, and the regression equations are used to describe and reflect the laws between the variables.

(1) Covariance diagnosis

Before conducting multiple linear regression analysis, it is necessary to diagnose the covariance between independent variables to avoid multiple covariance interfering with the regression results. Here the coefficient of variance inflation is used to test the measurement, and the covariance diagnosis results are shown in Table 5. When the variance inflation coefficient is higher than 10, it indicates that the problem of multicollinearity between the variables is very serious. It can be seen that the variance inflation coefficient for practice teaching is maximum 1.7163 and all the variables have variance inflation coefficients less than the critical value of 10. It is deduced that the measurement variables are generally not affected by multicollinearity.

Table 5. Collinearity diagnostic results.

Influencing factor	Linear correlation statistics	
	Tolerate	VIF
Course offered	0.5361	1.3504
Teacher factors	0.7238	1.2782

Practical teaching	1.0889	1.3502
Teaching Support	0.7443	1.3979
Teaching management	0.7371	1.7163

(2) Regression analysis

The overall satisfaction of physical education teaching and the five independent variables were introduced into the multiple linear regression equation, and the regression results were obtained, and the results of the multiple regression analysis of the influencing factors of teaching satisfaction are shown in Table 6. In this study, students' overall satisfaction with teaching was set as the dependent variable Y, and five specific teaching factors, namely, "curriculum, teachers' factors, practical teaching, teaching security, and teaching management" were set as the independent variables X, which were expressed as X1, X2, X3, X4, and X5, respectively. Based on the results the standardized regression equation can be written as $Y = 0.2747 + 0.4278X1 + 0.3514X2 + 0.3362X3 + 0.4065X4 + 0.4357X5$. The value of the regression coefficient is used to reflect the degree to which different factors affect the overall satisfaction of physical education teaching, and the larger the absolute value of the regression coefficient, the more significantly it can affect the overall satisfaction of teaching. From the linear regression model, it can be seen that the five independent variables, namely, curriculum, teacher factors, practical teaching, teaching guarantee, and teaching management, have a positive impact on the overall satisfaction of physical education teaching. The standardized regression coefficient of teaching management, which is the most important factor affecting student satisfaction, is 0.4357. The implication is that for every one unit increase in satisfaction with instructional management, students' overall satisfaction with physical education instruction can increase by 0.4357 units, holding other study variables constant, and so on for each of the other standardized regression coefficients. The R^2 of the regression model for the factors influencing students' satisfaction with physical education instruction was 0.5632, indicating that the independent variable of these five instructional dimensions explained 56.32% of the overall satisfaction with instruction of the dependent variable. The p-value is significant at the 0.01 level, there is a significant positive correlation between the independent variable of teaching satisfaction and the dependent variable, the linear relationship of the regression model is significant, the equation obtained from this fit is statistically significant, and the conclusion can be basically extrapolated to the whole.

Table 6. Multiple regression analysis of factors affecting teaching satisfaction.

Model	Non-standardized coefficients		Standard coefficient	t	Conspicuousness
	B	Standard Error	Beytagh		
Constant	0.2747	0.2171		0.3538	0.6992
Course offered	0.4278	0.0475	0.2322	4.547	0.0000
Teacher factors	0.3514	0.056	0.1347	2.636	0.0061
Practical teaching	0.3362	0.0466	0.1513	2.7068	0.0054
Teaching Support	0.4065	0.0545	0.1675	3.4073	0.0007
Teaching management	0.4357	0.0495	0.2294	4.5012	0.0000
R^2	0.5632				
F	52.9527				
P	0.0000				

3.3. Countermeasures to Improve the Satisfaction of Physical Education Teaching and Teaching Quality

Students are the main body of teaching, pay attention to the student group satisfaction assessment research, can timely understand the specific views of students on the satisfaction of physical education teaching, better find the advantages and shortcomings of physical education teaching services in colleges and universities, to help make up for their strengths and weaknesses, and promote the steady improvement of the quality of physical education teaching services.

The normal development of physical education and teaching activities involves many factors, which are concentrated in the five parts of “curriculum, teacher factors, practical teaching, teaching security, teaching management”. If the influencing factors of physical education teaching are not accurately identified, it will definitely affect the learning experience of students and the improvement of the teaching effect of physical education in schools. Based on this, this paper focuses on the five influencing factors mentioned in the previous article, namely, “curriculum, teacher factors, practice teaching, teaching security, teaching management”, and puts forward countermeasures to improve the satisfaction and quality of physical education teaching. The specific countermeasures are as follows:

(1) Countermeasures to improve the dimension of teaching management: ① Help students to clarify their learning objectives; ② Improve the management system of physical education teaching; ③ Systematically carry out employment services related to physical education.

(2) Countermeasures to improve the dimension of curriculum: ① innovate the way of presenting teaching materials; ② deepen the reform of public basic courses.

(3) Countermeasures to improve the dimension of teaching guarantee: ① optimize the practical training environment; ② give full play to the advantages of internal campus resources.

(4) Countermeasures to improve the dimension of teachers: ① develop sports specialized education; ② do a good job in teacher training.

(5) Countermeasures to improve the dimension of practical teaching: ① Establish a two-way communication mechanism between schools and enterprises; ② Adjust the assessment methods of practical courses.

4. Conclusion

This study applied a multiple linear regression model to analyze the correlation between the influencing factors and satisfaction with physical education teaching. The main conclusions are as follows:

(1) The scores of the five dimensions of curriculum, teacher factors, practice teaching, teaching guarantee and teaching management on the satisfaction of physical education teaching are all above 3.5, and they are ranked in descending order according to their influence on the satisfaction of physical education teaching as follows: practice teaching>curriculum>teacher factors>teaching management>teacher guarantee.

(2) Students' satisfaction with physical education teaching is not related to students' gender and grade, but is related to their majors, especially there is a significant difference between physical education majors and non-physical education majors in terms of influencing factors such as curriculum and teacher factors ($P<0.05$).

(3) There is a moderate positive correlation ([0.514,0.748]) between students' satisfaction with physical education teaching in terms of curriculum, teachers' factors, practice teaching, teaching security, and teaching management, and the degree of explanation of these five dimensions of teaching (the independent variables) to the overall satisfaction with teaching (the dependent variable) is as high as 56.32%. It shows that there is a significant positive correlation between the independent and dependent variables of teaching satisfaction, which proves that regression analysis method is statistically significant in the identification of factors affecting teaching satisfaction in physical education.

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