Research on Factors of Linear Algebra Learning Effect

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Abstract
Linear algebra has a very important application in physics and technical disciplines. This article conducted a questionnaire survey on the factors that affect the effect of linear algebra learning; the questionnaire contains several aspects of learning attitude, learning interest, learning methods, teaching methods, etc.; based on recycling data, cross chi-square test and multiple logistic regression analysis are used to obtain the factors that affect the effect of linear algebra learning. The research results show that: learning methods, learning attitudes, teaching methods and elementary algebra basics are the main factors that affect the learning effect of linear algebra; among them, there are positive correlations between teaching methods, learning methods, and elementary algebra basics; there are positive correlations between teaching methods, learning methods, and elementary algebra basics. The three principal components of learning attitude are positively correlated. Based on the research and analysis, the following conclusions are drawn: finding a suitable learning method for the college students and maintaining a positive learning attitude are effective means to improve the linear algebra learning effect of the college students; in teaching, it is recommended to advance with the times, the teaching content and teaching methods innovate to stimulate students’ interest in learning, thus improving the learning effect of college students’ linear algebra courses.

Keywords
Linear Algebra, Learning Effect, Influencing Factors

1. Introduction
Linear algebra is an indispensable basic mathematics course for non-mathematics majors such as science and engineering majors and economic management ma-
jors in colleges and universities. It plays an important role in cultivating students’ mathematical quality and mathematical ability. However, the actual situation today is not optimistic, because the content of linear algebra courses is more and more complex and abstract; the content of the courses does not match the teaching hours; the traditional teaching mode still occupies the mainstream in today's teaching and other factors, resulting in low student initiative; in order to complete the teaching tasks, the teaching content set by themselves has to be limited to books; students rarely interpenetrate, associate, and apply linear algebra with other subjects. Therefore, it is very necessary to study the factors that affect the learning effect of linear algebra courses for college students. However, the current domestic papers on the effects of linear algebra study are all in the form of discussion, generally summarize the main factors affecting the learning effect, and then give suggestions. This article uses the actual collected data as the basis, through mathematical modeling to obtain the main influencing factors that affect students’ linear algebra learning effect.

In [1], it is about stimulating students’ interest in learning by improving teaching methods and increasing their enthusiasm for learning, so as to achieve good learning results.

In [2], starting from the current status of linear algebra learning, the influencing factors of the learning effect of the linear algebra course are discussed in terms of students’ learning attitudes, learning methods, learning needs and teaching.

Reference [3], combined with its own teaching practice, discusses how to improve the quality of linear algebra teaching from the aspects of teaching methods and teaching methods.

In [4], according to the characteristics of the course “Linear Algebra”, combined with its own teaching experience, suggestions are made from the aspects of cultivating students’ interest in learning and improving teaching methods.

In [5], through the analysis of linear algebra course characteristics and academic conditions, the effects of linear algebra learning were studied in terms of enriching teaching methods, enhancing students’ learning initiative, and stimulating students’ interest in learning.

This article mainly analyzes the influencing factors of the linear algebra course, uses chi-square test to study and analyze the demographic variables and the initial algebra foundation; establish the correlation analysis and the establishment of the mathematical model of multiple logistic regression, and finally get the main impact of the linear algebra course learning effect Factors, hoping to provide guidance and suggestions for college students in linear algebra learning.

2. Research Objects and Methods

2.1. Research Object

The questionnaire survey target is college students in Baoding. Baoding is one of
the central cities in the Beijing-Tianjin-Hebei region. There are 18 colleges and universities that provide a good environment for data collection. A total of 700 questionnaires were distributed and valid questionnaires were returned. For 687 copies, the survey information is summarized in Table 1, and Table 2.

2.2. Research Tools

The content of the questionnaire is divided into learning methods, learning attitudes, teaching methods, etc. The overall reliability coefficient of the scale question of this questionnaire reached 0.762, which reached a good reliability level [see Table 3].

Through the tests, the approximate chi-square of the questionnaire is 3032.915, and the validity reaches 0.888 [see Table 4].

Table 1. Demographic variables.

| gender    | Frequency | Percentage | Effective Percentage | Cumulative Percentage |
|-----------|-----------|------------|----------------------|-----------------------|
| Male      | 210       | 30.6       | 30.6                 | 30.6                  |
| Female    | 477       | 69.4       | 69.4                 | 100                   |
| Total     | 687       | 100        | 100                  |                       |

Table 2. Demographic variables.

| grade      | Frequency | Percentage | Effective Percentage | Cumulative Percentage |
|------------|-----------|------------|----------------------|-----------------------|
| First grade| 115       | 16.7       | 16.7                 | 16.7                  |
| Sophomore  | 147       | 21.4       | 21.4                 | 38.1                  |
| Third grade| 139       | 20.2       | 20.2                 | 58.4                  |
| Fourth grade| 286      | 41.6       | 41.6                 | 100                   |
| Total      | 687       | 100        | 100                  |                       |

Table 3. Reliability.

| Reliability statistics          | Cronbach’s Alpha | Number of items |
|---------------------------------|------------------|-----------------|
|                                 | 0.762            | 18              |

Table 4. Validity.

| KMO and Bartlett’s test          | Sampling enough measurements Kaiser-Meyer-Olkin | Approximate chi-square | Bartlett’s Sphericity test |
|----------------------------------|-------------------------------------------------|------------------------|---------------------------|
|                                 | 0.888                                            | 3032.915               | df                        |
|                                 |                                                  |                        | Sig.                       |
|                                 |                                                  |                        | 0.000                     |
2.3. Statistical Analysis and Data Processing

The software is used to process the data, and the difference between demographic variables and elementary algebra is cross-chi-squared; the factors that affect the effect of linear algebra learning and the correlation between the factors are analyzed by correlation analysis and multiple regression analysis.

3. Research Results and Analysis

Two types of data are involved in the questionnaire, which are quantitative and categorical data. Quantitative data are generally continuous data in mathematics, and the more common in questionnaires are scales; categorical data is generally mathematics. Discrete data, such as gender and age, are more common in the questionnaire. This questionnaire has both categorized and quantitative data, so it uses cross-chi-square, correlation analysis, and multiple regression methods.

3.1. Cross Chi-Square Test

3.1.1. Gender

It can be seen from the cross-table analysis that the Pearson chi-square value of gender on linear algebra is greater than 0.05, indicating that gender has no significant effect on the learning effect of linear algebra; while the value and the value are less than 0.1, the relationship is not close, that is, the effect of gender on the linear algebra learning No obvious relationship [see Table 5 and Table 6].

3.1.2. Grade

A questionnaire survey was conducted on students of different grades in various colleges.

Table 5. Gender and linear algebra.

| Chi-square test                        | Value       | df | Progressive Sig. (two-sided) |
|----------------------------------------|-------------|----|------------------------------|
| Pearson chi-square                     | 1.204a      | 3  | 0.752                        |
| Likelihood ratio                       | 1.148       | 3  | 0.765                        |
| Linear and linear combination          | 0.043       | 1  | 0.835                        |
| N in valid cases                       | 687         |    |                              |

a. The expected count of 0 cells (0%) is less than 5. The minimum expected count is 6.72.

Table 6. Corresponding phi value and v value.

| Symmetry                               | Value | Approximate Sig. |
|----------------------------------------|-------|-----------------|
| Calibration by scalar                  | 0.042 | 0.752           |
| Cramer’s v                             | 0.042 | 0.752           |
| N in valid cases                       | 687   |                 |
It can be seen from the cross-table analysis that the Pearson chi-square value of grade for linear algebra is less than 0.05, indicating that grade has a significant effect on the learning effect of linear algebra. At the same time, the value and the value are greater than 0.1, indicating that the relationship is close, that is, the grade has a linear algebra learning effect. There is an obvious relationship.

### 3.1.3. Results with Elementary Algebra

From the cross-table analysis, it can be seen that the Pearson chi-square value of elementary algebra on linear algebra is less than 0.05, indicating that elementary algebra has a significant effect on the learning effect of linear algebra; while the value and the value are greater than 0.1, it means that the relationship between elementary algebra and linear algebra is close, that is, elementary algebra is linear. There is a clear relationship between learning effectiveness.

### 3.2. Related Analysis [6]

Before conducting relevant analysis, it is necessary to reduce the dimensionality of all questions in the questionnaire, that is, the closest content in the questionnaire question is classified into one category, and the non-close content is divided into different categories, the distance within the group is the shortest, and the distance between the groups is the farthest.

#### 3.2.1. Dimensionality Reduction

Use principal component factor analysis to achieve dimensionality reduction, dimensionality reduction steps [see Table 7(a) and Table 7(b)]:

1) Form the original data into a matrix by row, and name this matrix $A$;
2) Subtract the average value of each row of matrix $A$ from each row, and the sample mean formula is:

$$
\bar{x} = \frac{x_1 + x_2 + \cdots + x_m}{m}
$$

(1)

3) Find the correlation coefficient matrix $C$ corresponding to the variable

$$
C = \frac{1}{m} A^T A
$$

(2)

4) Find the eigenvalue and eigenvector corresponding to the correlation coefficient matrix $C$; the eigenvalue and eigenvector of the data matrix

$$
\lambda E - C = 0
$$

(3)

Each characteristic value is obtained from the SPSS analysis results:

$$
\lambda_1 = 4.888, \lambda_2 = 1.178, \lambda_3 = 1.162, \lambda_4 = 0.868, \lambda_5 = 0.710,
\lambda_6 = 0.694, \lambda_7 = 0.670, \lambda_8 = 0.566, \lambda_9 = 0.525, \lambda_{10} = 0.490,
\lambda_{11} = 0.468, \lambda_{12} = 0.433, \lambda_{13} = 0.412, \lambda_{14} = 0.328
$$

Sort the calculated feature values in descending order, and then calculate the corresponding feature vector, that is

$$
(\lambda E - C) x_i = 0 \ (i = 1, 2, \ldots, 14)
$$

(4)
Table 7. Correlation matrix.

(a)

|       | Q5   | Q6   | Q7   | Q8   | Q9   | Q10  | Q11  |
|-------|------|------|------|------|------|------|------|
| Q5    |      | 1    | 0.54 | 0.391| 0.348| 0.504| 0.138| 0.31 |
| Q6    | 0.54 |      | 1    | 0.462| 0.329| 0.55 | 0.14 | 0.28 |
| Q7    | 0.391| 0.462|      | 1    | 0.37 | 0.442| 0.193| 0.258|
| Q8    | 0.348| 0.329| 0.37 |      | 1    | 0.349| 0.259| 0.368|
| Q9    | 0.504| 0.55 | 0.442| 0.349|      | 1    | 0.195| 0.313|
| Q10   | 0.138| 0.14 | 0.193| 0.259| 0.195|      | 1    | 0.25 |
| Q11   | 0.31 | 0.28 | 0.258| 0.368| 0.313| 0.25 |      | 1    |

(b)

|       | Q12  | Q13  | Q14  | Q16  | Q17  | Q18  | Q19  |
|-------|------|------|------|------|------|------|------|
| Q5    | 0.204| 0.344| 0.315| 0.234| 0.193| 0.262| 0.283|
| Q6    | 0.219| 0.352| 0.329| 0.182| 0.181| 0.261| 0.227|
| Q7    | 0.187| 0.339| 0.298| 0.229| 0.172| 0.189| 0.198|
| Q8    | 0.232| 0.446| 0.361| 0.208| 0.206| 0.172| 0.174|
| Q9    | 0.224| 0.375| 0.338| 0.228| 0.208| 0.246| 0.241|
| Q10   | 0.16 | 0.314| 0.252| 0.16 | 0.18 | 0.092| 0.113|
| Q11   | 0.331| 0.408| 0.291| 0.253| 0.256| 0.307| 0.316|

5) Sort the obtained eigenvectors from largest to smallest eigenvalues, and take the first $K$ to form the matrix $P$; the values of the matrix $P$ are shown in Table 8.

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Table 8. Correlation matrix.

| Ingredients                                      | 1     | 2     | 3     |
|--------------------------------------------------|-------|-------|-------|
| Effective preview                                | 0.128 | 0.166 | −0.314|
| Regularly review what you have learned           | 0.128 | 0.209 | −0.335|
| The habit of wrong questions or key records      | 0.118 | 0.194 | −0.183|
| High concentration of lectures                    | 0.119 | 0.173 | 0.192 |
| There are plans for free time after class         | 0.132 | 0.195 | −0.251|
| Take each test seriously                         | 0.078 | 0.081 | 0.469 |
| Actively interact with teachers                   | 0.123 | 0.023 | 0.228 |
| Recognize the importance of the course            | 0.106 | −0.049| 0.296 |
| Positive learning attitude                        | 0.143 | 0.066 | 0.292 |
| The quality of job completion is better           | 0.115 | 0.132 | 0.177 |
| The teacher teaches classic math cases to stimulate curiosity | 0.119 | −0.281| −0.061|
| Teachers have various teaching methods            | 0.117 | −0.297| −0.012|
| Teachers in the class will create problem situations and heuristic teaching | 0.127 | −0.306| −0.152|
| The teacher’s teaching method is rich             | 0.128 | −0.302| −0.117|

6) After passing the formula. $B = CP$, $B$ is the result after dimensionality reduction

$$b_j = \sum_{i=1}^{14} c_i p_i; (i = 1, 2, 3, \ldots, 14)( j = 1, 2, 3)$$

where $p_i$ represents the feature vector, and $c_i$ represents the variable sequence of the $i$th question. Substitute the corresponding values into:

$$b_1 = 0.128c_1 + 0.128c_2 + 0.118c_3 + 0.119c_4 + 0.132c_5 + 0.078c_6 + 0.123c_7$$
$$+ 0.106c_8 + 0.143c_9 + 0.115c_{10} + 0.119c_{11} + 0.117c_{12} + 0.127c_{13} + 0.128c_{14}$$

$$b_2 = 0.166c_1 + 0.296c_2 + 0.194c_3 + 0.173c_4 + 0.195c_5 + 0.081c_6 + 0.023c_7$$
$$- 0.049c_8 + 0.066c_9 + 0.132c_{10} - 0.281c_{11} - 0.297c_{12} - 0.306c_{13} - 0.302c_{14}$$

$$b_3 = -0.314c_1 - 0.335c_2 - 0.183c_3 + 0.192c_4 - 0.251c_5 + 0.469c_6 + 0.228c_7$$
$$+ 0.296c_8 + 0.292c_9 + 0.117c_{10} - 0.061c_{11} - 0.012c_{12} - 0.152c_{13} - 0.117c_{14}$$

so as to get the final dimensionality reduction result.

Before using factor analysis for dimensionality reduction, you need to check the suitability of the sample’s factor analysis through the KMO and Bartlett spherical tests; the KMO value of this article is 0.859. It reached a good level of fit [see Table 9].

3.2.2. Model Principle

Correlation analysis is a statistical method to study whether there is a correlation between random variables. Calculation of correlation coefficient:

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Table 9. Explained total variance.

| Ingredients | Extract square sum load | Rotate square sum loading |
|-------------|-------------------------|--------------------------|
| Total       | % Of variance | Cumulative % | Total       | % Of variance | Cumulative % | Total       | % Of variance | Cumulative % |
| 1           | 4.097        | 40.97        | 37.245      | 37.245       | 2.692        | 24.469      | 24.469       |
| 2           | 1.744        | 17.44        | 15.856      | 53.101       | 2.675        | 24.322      | 48.792       |
| 3           | 1.055        | 10.55        | 9.589       | 62.69        | 1.529        | 13.898      | 62.69        |
| 4           | 0.702        | 7.02         | 6.378       | 69.069       |              |             |              |
| 5           | 0.644        | 6.44         | 5.851       | 74.92        |              |             |              |
| 6           | 0.565        | 5.65         | 5.137       | 80.057       |              |             |              |
| 7           | 0.498        | 4.98         | 4.525       | 84.582       |              |             |              |
| 8           | 0.487        | 4.87         | 4.426       | 89.009       |              |             |              |
| 9           | 0.449        | 4.49         | 4.078       | 93.086       |              |             |              |
| 10          | 0.328        | 3.28         | 2.981       | 97.019       |              |             |              |

\[ r = \frac{l_{ij}}{\sqrt{l_{ii}l_{jj}}} = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2} \sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}} \]  

(6)

where \( l_{ij} \) represents the covariance of variables \( i \) and \( j \); \( \bar{X} \) represents the mean of the variables.

Judging from the scatterplot that there is a linear relationship between the three principal components, the Pearson correlation analysis is used to obtain [see Table 10].

3.2.3. Results and Analysis

Empathy

\[ r_{12} = \frac{l_{12}}{\sqrt{l_{11}l_{22}}} = \frac{0.1}{\sqrt{0.782 \times 0.150}} = 0.291 \]  

(7)

The subscript of \( r \) is 1 line generation learning effect, 2 learning method, 3 teaching method, 4 learning attitude.

It can be seen from the above table that the correlation coefficient between linear algebra scores and learning methods is 0.291, and the value is less than 0.05. Therefore, the positive correlation between the two variables is statistically significant, and the linear algebra learning effect increases with the suitability of the learning method. In the same way, the correlation coefficients of linear algebra and learning attitude and teaching methods are 0.334 and 0.080, and the values are both less than 0.05, and the positive correlation between the two variables is
Table 10. Correlation.

|                     | Teaching Method | Learning Method | Learning Attitude | Linear Algebra Results |
|---------------------|-----------------|-----------------|-------------------|------------------------|
| Pearson Correlation | 1               | 0.348**         | 0.338**           | 0.080*                 |
| Significance (both sides) | 0               | 0               | 0.037             |                        |
| Sum of square and cross product | 126.226 | 39.619         | 27.414            | 20.707                 |
| Covariance          | 0.184           | 0.058           | 0.04              | 0.03                   |
| N                   | 687             | 687             | 687               | 687                    |
| Pearson Correlation | 0.348**         | 1               | 0.483**           | 0.291**                |
| Significance (both sides) | 0              | 0               | 0                 |                        |
| Sum of square and cross product | 39.619 | 102.693         | 35.322            | 68.288                 |
| Covariance          | 0.058           | 0.15            | 0.051             | 0.1                    |
| N                   | 687             | 687             | 687               | 687                    |
| Pearson Correlation | 0.338**         | 0.483**         | 1                 | 0.334**                |
| Significance (both sides) | 0              | 0               | 0                 |                        |
| Sum of square and cross product | 27.414 | 35.322         | 52.07             | 55.876                 |
| Covariance          | 0.04            | 0.051           | 0.076             | 0.081                  |
| N                   | 687             | 687             | 687               | 687                    |
| Pearson Correlation | 0.080*          | 0.291**         | 0.334**           | 1                      |
| Significance (both sides) | 0.037     | 0               | 0                 |                        |
| Sum of square and cross product | 20.707 | 68.288         | 55.876            | 536.509                |
| Covariance          | 0.03            | 0.1             | 0.081             | 0.782                  |
| N                   | 687             | 687             | 687               | 687                    |

**. Significantly correlated at 0.01 level (both sides); *. Significantly correlated at the 0.05 level (both sides).

Also statistically significant, that is, the more positive the learning attitude, the more effective the linear algebra learning effect; the more the teaching method is recognized by the students, the better the effect of online learning [see Table 11].

\[
\gamma_{12} = \frac{l_{12}}{\sqrt{l_{11}l_{22}}} = \frac{0.058}{\sqrt{0.150 \times 0.184}} = 0.348
\]

\[
\gamma_{13} = \frac{l_{13}}{\sqrt{l_{11}l_{33}}} = \frac{0.051}{\sqrt{0.150 \times 0.076}} = 0.483
\]
Table 11. Correlation between the three principal components.

| Correlation between the three principal components | Teaching Method | Learning Attitude | Learning Method |
|--------------------------------------------------|-----------------|-------------------|----------------|
| Teaching Method                                  | Pearson Correlation | 1.000**          | 0.348**        |
| Significance (both sides)                        | 0.000           | 0.000             | 0.000          |
| Sum of square and cross product                  | 126.226         | 27.414            | 39.619         |
| Covariance                                       | 0.184           | 0.04              | 0.058          |
| N                                               | 687             | 687               | 687            |
| Learning Attitude                                | Pearson Correlation | 0.338**          | 1.000          | 0.483**        |
| Significance (both sides)                        | 0.000           | 0.000             | 0.000          |
| Sum of square and cross product                  | 27.414          | 52.07             | 35.322         |
| Covariance                                       | 0.04            | 0.076             | 0.051          |
| N                                               | 687             | 687               | 687            |
| Learning Method                                  | Pearson Correlation | 0.348**          | 0.483**        | 1.000          |
| Significance (both sides)                        | 0.000           | 0.000             | 0.000          |
| Sum of square and cross product                  | 39.619          | 35.322            | 102.693        |
| Covariance                                       | 0.058           | 0.051             | 0.15           |
| N                                               | 687             | 687               | 687            |

**. Significantly correlated at 0.01 level (both sides).

The 1 in the lower subscript of $r$ is the learning method, 2 is the teaching method, and 3 is the learning attitude; the upper subscript of $r$ is the correlation coefficient for distinguishing the line generation and the three principal components.

We can see from the correlation table between the three principal components that there is a significant positive correlation between the three major components.

3.3. Multiple Logistic Regression [7]

3.3.1. Model Introduction

Multiple logistic regression studies whether the variable $X$ will affect $Y$.

The multiple logistic regression equation is:

\[
\logit(P_x) = \ln \left( \frac{P(Y = b)}{P(Y = a)} \right) = \beta_0 + \beta_{11}X_1 + \beta_{12}X_2 + \cdots + \beta_{1p}X_p 
\]  (8)

\[
\logit(P_y) = \ln \left( \frac{P(Y = c)}{P(Y = a)} \right) = \beta_0 + \beta_{11}X_1 + \beta_{12}X_2 + \cdots + \beta_{1p}X_p 
\]  (9)

where $Y = a$ is the control group of $b$ and $c$. 
3.3.2. Results and Analysis
Likelihood ratio test results show whether the model has statistical significance; the independent variable learning method, the addition of learning attitude is statistically significant ($p < 0.001$), the independent variable teaching method has no significant effect on the dependent variable.

\[
\text{logit}(P_j) = \ln \left( \frac{P(Y = b)}{P(Y = a)} \right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \\
= 3.078 + 0.483x_1 - 0.394x_2 - 1.956x_3
\]

(10)

Empathy

\[
\text{logit}(P_j) = 5.544 + 0.55x_1 - 1.259x_2 - 2.752x_3 \\
\text{logit}(P_j) = 5.023 + 0.41x_1 - 1.823x_2 - 3.246x_3
\]

The above formula $a$ indicates the reference category, that is, the line generation score is more than 85 points, $b$ is the linear algebra score from 75 to 85 points, $c$ is the linear algebra score from 60 to 75 points, and $d$ represents the linear algebra score is 60 points below; $ij$ represents the corresponding $B$ value in the parameter estimation table; $P_b$ represents the probability of event $b$ compared to event $a$.

4. Conclusions

1) Learning attitudes, learning methods, elementary algebra and grade all have a significant impact on the effects of linear algebra learning; teaching methods have a slightly lower impact on the effects of linear algebra learning; gender will not have a significant impact on the effects of linear algebra learning.

2) Your own learning method and good learning attitude are effective means to achieve good learning effect.

3) Teachers can make appropriate innovations in teaching content and teaching methods, and improve the teaching level by increasing students’ interest in learning.

This article mainly analyzes the influencing factors of the linear algebra course, uses chi-square test to study and analyze the demographic variables and the initial algebra foundation; establishes the correlation analysis and the mathematical model of multiple logistic regression; and finally gets the main impact of the linear algebra course learning effect factors, hoping to provide guidance and suggestions for college students in linear algebra learning.

This article has studied the effects of linear algebra learning on college students, but the specific effects of grades, elementary algebra, etc. on the effects of linear algebra learning can be further studied.

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**Conflicts of Interest**

The authors declare no conflicts of interest regarding the publication of this paper.

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