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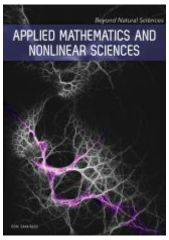

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The effect of implementing metacognitive strategies in computer-assisted instruction on student learning outcomes

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Abstract

The rapid development of information technology promotes the popularization of computer-assisted teaching in colleges and universities, and the diversification of information access brings challenges to students’ learning, so the metacognitive learning strategy has received more and more attention. In order to explore the influence of metacognitive strategies on students’ learning effectiveness, this paper selects first-year students majoring in Business English in a university as the research object, develops and distributes the Questionnaire on the Application of Metacognitive Strategies, sets up experimental and control classes to carry out the practice of applying metacognitive strategies in computer-assisted teaching and processes the data with correlation analysis and multiple regression analysis. The total metacognitive score of the experimental class was as high as 141.83 after the practice, which showed a significant difference compared with the pre-test (P=0.007<0.01). Compared to the pre-practice period, the scores of the questionnaire questions for the three sub-strategies of planning strategy, monitoring strategy, and evaluation strategy increased by an average of 0.952, 1.614, and 1.444, respectively.The implementation of metacognitive strategies has a significant impact on students’ learning effectiveness.

Keywords: Correlation coefficient; Multiple regression model; Least squares; Metacognitive strategies.
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1 Introduction

Nowadays, computers play an increasingly important role in language teaching. Color and efficiency are brought about through multiple inputs: hypertext, images, audio and video clips [1-2]. With the development of multimedia computers and web-based learning, the constructivist theory is showing its power more and more because multimedia computers and web-based technologies are suitable for constructivist practices, in other words, multimedia computers and web-based technologies can be used as an ideal cognitive approach to facilitate students' cognitive construction [3-6].

Autonomous learning plays an important role in the student learning process. However, some students do not do well enough in a more autonomous learning environment. This suggests that students in autonomous environments need some strategic guidance in planning, monitoring, and evaluating [7-9]. Self-directed learning includes self-regulation, self-monitoring and self-evaluation, which are components of metacognitive learning strategies. Therefore, metacognitive learning strategies are the focus of current research. Metacognitive learning strategies are highly related to the acquisition of goals [10-11]. Metacognitive strategies are "higher-order executive skills that are applicable to a variety of learning tasks". In other words, metacognitive strategies that allow students to plan, control, and assess their learning play a central role [12-13].

The pioneer of metacognitive research is the American psychologist Flavell, who believes that metacognition is about the individual's self-regulation, introspection, and evaluation of his or her own cognitive processes, and the regulation and awareness of the individual's thinking and learning activities during the learning process [14-15]. Therefore, in the process of learning, the level of metacognitive development of students has an important impact on the effect of learning. Therefore, it is particularly important for teachers to develop students' metacognitive level in the teaching process [16-17].

With the wide application in the field of computer and the continuous progress of multimedia technology, the status of CAI in modern teaching is rising [18]. The intervention of CAI has both advantages and disadvantages. The advantageous aspect lies in the fact that, through a large number of pictures and animations, students can accept knowledge through multiple senses, and the abstract theoretical knowledge can be dynamized, which can greatly improve the students' perceptual understanding of knowledge, thus stimulating the students' interest in learning and enthusiasm, on the other hand, the teacher in the process of lesson preparation, searching for the knowledge related to the teaching content through the rich network world, which increases the amount of classroom information, and to a certain extent, it not only saves the limited classroom knowledge, but also saves the classroom information. On the other hand, teachers search for knowledge related to the teaching content through the rich network world in the process of lesson preparation, which increases the amount of information in the classroom, which to a certain extent not only saves the limited time in the classroom, but also greatly improves the effect of teaching, the disadvantage of which lies in the fact that there are still some limitations of CAI in the process of teaching, such as the students in the process of teaching are only concerned about looking at the screen, and the teacher is busy with the increase in the amount of information, which ignores the interaction between teachers and students in the process of teaching, and in addition, some of the students are too busy copying the content of the screen, to keep up with the teacher's ideas of teaching [19-23].

The 21st century is the era of knowledge economy, the purpose of traditional education has occurred to cultivate the comprehensive quality of students as the purpose of the direction of the transformation, under this transformation, computer-assisted instruction (referred to as CAI) has penetrated into the teaching of various disciplines, how to rationally use the new mode of teaching on top of the original

CAI - SSL pedagogical method, to cultivate the individual's metacognitive ability, which is particularly important [24].

In this study, the influence of metacognitive strategies on students' learning effectiveness is selected as the research theme, the conceptual theory of metacognition as its strategies is proposed, and the research method is developed to determine the research object and research tools, and the correlation score analysis method and multiple regression model are proposed in data processing and analysis to explore the effectiveness of the metacognitive strategies on students' learning in computer-assisted teaching and learning, with the first year students of business English majors in a university as the research object. The first year students of Business English major in a university were taken as the object of the study, and the experimental class and the control class were set up to practice the application of metacognitive strategies in computer-assisted teaching, and the changes in the metacognitive level of the experimental class were analyzed from the mean values of the dimensions of metacognitive level and the scores of the corresponding questionnaire. The correlation and influence of metacognitive strategies on learning effectiveness were analyzed using the correlation score analysis method and multiple regression model in this paper.

2 Research Design

2.1 Research Theory

The concept of "metacognition" belongs to the category of cognitive psychology, which is developed and extended from the study of "self-awareness". In this section, we will provide an overview and analysis of metacognition, metacognitive strategies and related concepts, and analyze the connotation and components of the concept of metacognition, so as to lay the foundation for the following discussion of the relationship between metacognition and online self-directed learning.

2.1.1 Metacognitive concepts

Metacognition expresses the core meaning of an individual's perception of their own cognitive processes, as well as self-monitoring, planning, and self-regulation based on this perception. This study proposes a system that captures the connotation of metacognition in terms of two types of components and three levels, as shown in Figure 1.

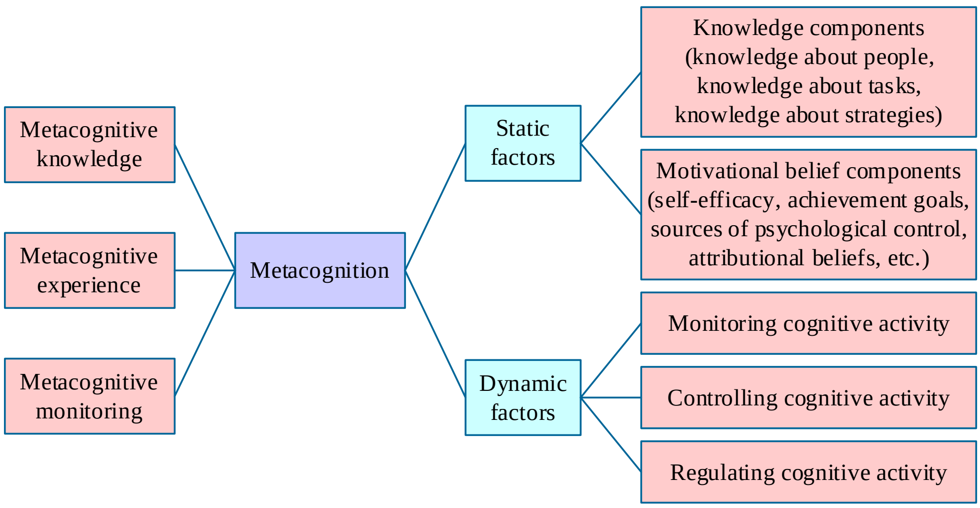

Figure 1. System of metacognitive meaning

First of all, metacognition includes two types of components, one is the conscious static factor, which is specifically subdivided into the knowledge component and the motivational beliefs component, the former includes knowledge about people, tasks and strategies, or understood from another perspective, including declarative, conditional and procedural knowledge. The latter includes self-efficacy, achievement goals, sources of psychological control, attributional beliefs, etc.; the other category is the dynamic component, which mainly includes metacognitive monitoring, control, and regulation, and these two categories of components are organically united in the individual. Static factors are the accumulation of dynamic factors and grow, modify, and change due to the activities of dynamic factors. The activities of dynamic factors are based on and constrained by static factors. The two components complement each other. In examining the level of individual metacognition, both types of components should be taken into account.

2.1.2 Metacognitive strategies

Metacognitive strategy is a typical learning strategy, which is a higher level executive strategy based on the theoretical system related to metacognition [25]. In this paper, we believe that a metacognitive strategy consists of two aspects: one is the static knowledge of the strategy, which reflects the degree of the individual's understanding of their own cognitive process. The second is the use of strategies, which is a dynamic process that includes three aspects: planning, monitoring, and evaluation, as shown in Figure 2. Strategy knowledge is to regulate the individual's attention, thinking ability and other factors of their own knowledge, it can be used declarative, procedural knowledge or conditional knowledge to control and regulate the individual's learning and cognitive processes, the essence of which can be understood as a set of rules and procedures to control the acquisition of human learning and thinking. The use of strategies involves the strategic regulation of activities, in which the planning strategy refers to the individual in the learning activities before the start of the establishment of learning goals, learning content, learning time, learning progress and learning strategies for the arrangement of planning; monitoring strategy refers to the process of learning activities, the learner according to the learning goals and plans to consciously implement the monitoring of the learning process, including whether the learning content has been digested, the choice of learning methods, whether the plan is fully implemented, and so on. Whether the learning content is digested, whether the learning method is selected appropriately, whether the plan is completely implemented, etc., this strategy is also an important factor in judging the learning effect; Evaluation strategy refers to the individual in the end of the learning activity, based on certain evaluation criteria for cognitive activities and strategies to reflect on, evaluate, and timely remediation of the problems and deficiencies that have arisen. Metacognitive strategies are based on metacognitive knowledge, and they are used in metacognitive experience and metacognitive monitoring. Therefore, metacognitive strategies and metacognition are both interrelated and interdependent.

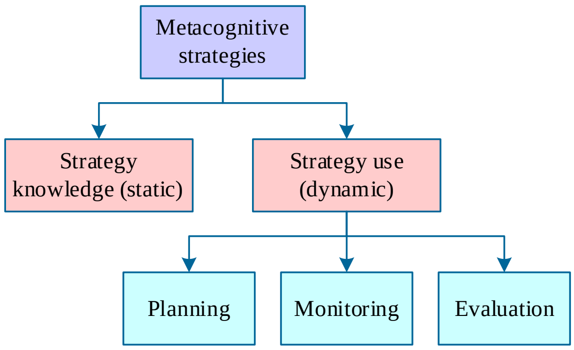

Figure 2. The process of meta-cognitive strategy

2.2 Research methodology

2.2.1 Research Objectives

This study is an empirical research on the impact of the implementation of metacognitive strategies on students' learning effectiveness in computer-assisted instruction. The study adopts a mixed research method of questionnaire survey plus experimental research plus interviews, and takes college students of a university as the research object, mainly examining and exploring the relationship between the implementation of cognitive strategies in computer-assisted teaching and students' learning effectiveness.

The sample of this study is 125 students in two first-year classes of Business English majors in this university. The first class is a control class with 62 students and the second class is an experimental class with 63 students. In the teaching practice, the experimental class was selected to conduct an experimental study on the application of metacognitive strategies in computer-assisted instruction, while the control class was taught routinely.

2.2.2 Research tools

Reading relevant research literature, referring to previous research results, and summarizing previous research experience, we designed the Metacognitive Strategy Examination Scale and tested the reliability and validity of the questionnaire a priori before formally distributing the Questionnaire on the Application of Metacognitive Strategies.

The questionnaire is mainly divided into three parts. The first part of the questionnaire investigates the learners' basic personal information, which mainly contains five items: nationality, gender, age, learning time, and learning level. The second part of the questionnaire investigates the learners' current learning status and examines their attitudes toward learning and the current application of learning strategies. The third part of the option scoring used Lecter's five-level scale to investigate the application of metacognitive strategies, with a total of 15 questions, of which questions 1-5, 6-10, and 11-15 examined the application of the three sub-strategies of planning, monitoring, and evaluating strategies, respectively. The details of the questionnaire topics are shown in Table 1.

Table 1. Subject contents of the questionnaire

Metacognitive strategy	Title symbol	Topic
Planning strategy	A1	When I study, I plan to use my time wisely to learn what to do.
	A2	Before you start learning, try to think about what you're going to learn and how to learn.
	A3	When you have a holiday, you always make a study plan for your vacation.
	A4	Often develop short-term learning programs
	A5	Be aware of your learning goals and tasks.
Monitoring strategy	B1	Often ask yourself about your knowledge.
	B2	I regularly ask myself if I have achieved my learning goals at the time of study.
	B3	Often pay attention to the problems encountered in the study and analyze the reasons.
	B4	In the course of learning, I can detect my original plan.
	B5	Often check the progress and effectiveness of the study.
Evaluation strategy	C1	In order to achieve better learning results, I will change my methods and strategies.
	C2	Often think about the questions and experiences you learn in your studies.
	C3	When you find that you can't achieve your chemistry goals, you adjust quickly and make new plans.
	C4	When you find that your learning time is not enough, increase your learning time.
	C5	When you're upset, take the right approach to calm your mind.

Questionnaires were conducted before and after the training on metacognitive strategies. Eighty-three questionnaires were distributed in the experimental and control classes before and after the training respectively, and 83 questionnaires were recovered. The recovery rate was 100% and the validity rate was 100%. The reliability and validity of the questionnaire were tested prior to the formal distribution of the Questionnaire on the Application of Metacognitive Strategies. The overall Clonbach Alpha coefficient of the questionnaire is 0.866, and after standardized statistics, the coefficient is 0.874, which is greater than 0.7, indicating that the questionnaire used in this study has a high degree of reliability. Validity is the validity of the questionnaire, and the validity mainly tests the degree of coincidence between the questionnaire measurements and the content of the examination, and the higher the degree of coincidence, the higher the validity. Measurement methods mainly test the KMO value and Bartlett's value, the KMO value is greater than 0.7 and the significance of Bartlett's test is less than or equal to 0.5, then the validity of the questionnaire meets the requirements. The KMO value of the "Metacognitive Strategies Application Questionnaire" used in this study is 0.781 greater than 0.7, and the significance is 0.012 less than 0.05, which shows that the structural validity of this paper's questionnaire is good and meets the requirements of the validity test to ensure that the results of the survey have the corresponding research value.

2.3 Data processing methods

2.3.1 Correlation analysis

Correlation analysis is the mathematical determination of an abstracted value reflecting the degree of linkage and direction of linkage between two equal sample aggregates, i.e., it is reflected by the correlation coefficient.

1) Characteristics of correlation coefficient

   The analysis of linear relationship between variables using correlation coefficient usually requires the completion of the following two steps [26]:

   Calculate the sample correlation coefficient r;

   (1) Correlation coefficient r takes values between -1 and +1.

   (2) $r > 0$ indicates that there is a positive linear correlation between the two variables; $r < 0$ indicates that there is a negative linear correlation between the two variables.

   (3) $r = 1$ indicates that there is a perfect positive correlation between the two variables; $r = -l$ indicates that there is a perfect negative correlation between the two variables; $r = 0$ indicates that the two variables are not correlated.

   (4) $|r| > 0.8$ means that there is a strong linear relationship between the two variables; $|r| < 0.3$ means that there is a weak linear relationship between the two variables.

   Inferences are made as to whether there is a significant linear relationship between the two totals from which the samples come.

   Due to the existence of random sampling and small sample size and other reasons, usually the sample correlation coefficient can not be used directly to indicate whether the sample from the overall significant linear correlation, but need to be tested by way of hypothesis testing on the sample from the overall existence of significant linear correlation of statistical inference. The basic steps are:

(1) Formulate the original hypothesis that there is no significant linear relationship between the two totals.

(2) Select the test statistic, i.e., different correlation coefficients.

(3) Calculate the observed value and the corresponding probability value of the test statistic.

(4) Decision making: the relationship between p and a.

2) Correlation coefficient analysis

Different correlation coefficients should be used to measure different types of variables, and the commonly used correlation coefficients mainly include Pearson simple correlation coefficient, Spearman rank correlation coefficient and Kendall τ correlation coefficient. The Pearson simple correlation coefficient is used here, which is applicable to the data that both variables are numerical, and its formula is:

$$R_{xy} = \frac{\sum_{i=1}^{n}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \overline{x})^2 \sum_{i=1}^{n}(y_i - \overline{y})^2}} \tag{1}$$

The test statistic for Pearson's simple correlation coefficient is:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \sim t(n-2) \tag{2}$$

2.3.2 Multiple regression models

Multiple regression analysis forecasting is a method of forecasting by modeling the quantitative change in the relationship between two or more independent variables and a dependent variable. The mathematical formula that expresses this quantitative relationship is called a multiple linear regression model.

In market economic activities, it is often encountered that the development and change of a certain market phenomenon is influenced by multiple factors, that is, a dependent variable and two or more independent variables have a dependent relationship. And sometimes it is difficult to distinguish the primary and secondary factors, or some factors are secondary, but their role can not be ignored. At this time, it is not possible to use the univariate regression analysis prediction method for prediction, and it is necessary to use the multiple regression analysis prediction method.

1) Calculation model of multiple linear regression

The multiple linear regression model is an extension of the univariate linear regression model, and its basic principles are similar to those of the univariate linear regression model, except that it is computationally more complex [27]. A multiple linear regression model is an equation that describes how the dependent variable y depends on the independent variable $x_1, x_2, \cdots\cdots x_k$ and the error term ε, and its general form is:

$$y = b_0 + b_1x_1 + b_2x_2 + \ldots + b_kx_k + \varepsilon \tag{3}$$

where: b_0 is a constant term that represents the estimate y when the respective variables are all 0; $b_1, b_2, \cdots, b_k$ is the sample bias regression coefficient, or the bias regression coefficient called y the counterpart of the $x_1, x_2, \cdots\cdots x_k$ bias regression coefficient, which represents the average amount of change in y for each unit change in $x_1, x_2, \cdots\cdots x_k$ the other independent variables when the other independent variables are unchanged; and ε is known as the error term for the random variable, which is the variability that is contained in the y but cannot be accounted for by the linear relationship between the k independent variables.

When the original information establishes the multivariate regression model, in order to ensure that the regression model has excellent explanatory ability and predictive effect, the theoretical conditions that should be satisfied are:

(1) Linearity, the relationship between the dependent variable and the independent variable is linear, that is to say, the independent variable has a significant effect on the dependent variable and has a close linear correlation;

(2) Independence, the random error term is independent across sample points, without autocorrelation. We have a random sample $\{(X_{i1}, X_{i2}, \cdots, X_{ik}, Y_i): i = 1, 2, \cdots, n\}$ containing n observation. This ensures that the error ε itself is random, i.e., free of autocorrelation, $Cov\left(\varepsilon_i - E\left(\varepsilon_i\right)\right)\left(\varepsilon_j - E\left(\varepsilon_j\right)\right) = 0$;

(3) Mutual exclusivity, the independent variables should be mutually exclusive, i.e., the independent variables should not be more correlated with each other than with the cause of the independent variable and the dependent variable;

(4) Completeness, the independent variables should have are complete statistics and their predictive values should be easily determined.

(5) Normality, the random error term obeys a normal distribution with zero mean and variance.

(6) Variance uniformity, the random error term has equal variance at different sample points.

2) Estimation of biased regression coefficients

One of the purposes of regression analysis is to establish regression equations that enable the researcher to predict the value of the dependent variable based on the known independent variables. The estimation of the partial regression coefficients for a multiple regression model, like the same linear regression equation, is done by solving the parameters by the least squares method under the requirement that the sum of squares of the errors $\left(\sum e^2\right)$ is minimized [28]. Taking the bilinear regression model as an example, the standard set of equations for solving the regression parameters is:

$$y = b_0 + b_1x_1 + b_2x_2, (k = 2) \tag{4}$$

$$B = \begin{bmatrix} b_0 \\ b_1 \\ b_2 \end{bmatrix}, X = \begin{pmatrix} 1 & x_{11} & x_{12} \\ \cdots & \cdots & \cdots \\ 1 & x_{n1} & x_{n2} \end{pmatrix} \tag{5}$$

The formula to derive b_0, b_1, b_2 is as follows:

$$\begin{cases} \sum y = nb_0 + b_1\sum x_1 + b_2\sum x_2 \\ \sum x_1 y = b_0\sum x_1 + b_1\sum x_1^2 + b_2\sum x_1x_2 \\ \sum x_2 y = b_0\sum x_2 + b_1\sum x_1x_2 + b_2\sum x_2^2 \end{cases} \tag{6}$$

Solve this equation to find the value of b_0, b_1, b_2. The following matrix method can also be used to find $b = (x'x)^{-1}?\ x'y$ that is:

$$\begin{bmatrix} b_0 \\ b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} n & \sum x_1 & \sum x_2 \\ \sum x_1 & \sum x_1^2 & \sum x_1x_2 \\ \sum x_2 & \sum x_1x_2 & \sum x_2^2 \end{bmatrix}^{-1} \cdot \begin{bmatrix} \sum y \\ \sum x_1 y \\ \sum x_2 y \end{bmatrix} \tag{7}$$

3) Multiple regression model test

Hypothesis testing of multiple regression model includes goodness-of-fit test, significance test of multiple regression equation as a whole and hypothesis test of partial regression coefficients.

A goodness-of-fit test is a test of the goodness of fit of a model to a sample of observations, which can be accomplished by constructing a statistic that expresses the degree of fit. Overall sum of squares $TSS = \sum(Y - \bar{Y})^2$, regression sum of squares $ESS = \sum(\hat{Y} - \bar{Y})^2$, residual sum of squares, $RSS = \sum(Y - \hat{Y})^2, \bar{Y}$ is the sample value, and $\hat{Y}$ is the estimated value. The relationship between them is $TSS = ESS + RSS$.

The goodness-of-fit test statistic can be coefficient of determination r^2:

$$r^2 = \frac{ESS}{TSS} = 1 - \frac{RSS}{TSS} \tag{8}$$

r^2 The closer to 1, the better the fit of the model.

The test of significance of the equation is designed to make an inference as to whether the linear relationship between the explanatory variables and the explanatory variables in the model holds significantly in the aggregate.

It can be proposed that the original hypothesis $b_1 = 0, b_2, \cdots, b_k = 0$ and alternative hypothesis b_i are not all 0. According to the definition of mathematical statistics, the statistics are as follows under the condition that the original hypothesis holds:

$$F = \frac{ESS/k}{RSS/(n-k-1)} \tag{9}$$

Obey a F distribution with $(k,n-k-1)$ degree of freedom. Given a significance level of α, a critical value $F\alpha(k,n-k-1)$ is obtained, and the value of the statistic F is derived from the sample, and the original hypothesis can be rejected or accepted by $F > F\alpha(k,n-k-1)$ or $F \le F\alpha(k,n-k-1)$ to determine whether the linear relationship on the whole of the original equation holds significantly.

Hypothesis testing of biased regression coefficients: t test. In this type of test, we need to make a statistically significant (i.e., with a certain level of confidence) test of whether a given (overall) parameter in the model satisfies the dummy's original hypothesis $b_i = a_i$, where a_i is some given known number. In particular, when $a_i = 0$, it is called a significance test for the parameter. If the original hypothesis is rejected, it means that the explanatory variable x_i has a significant linear effect on the explanatory variable Y, and the estimate $\hat{b}_i$ is daring to be used; conversely, it means that the explanatory variable x_i does not have a significant linear effect on the explanatory variable Y, and the estimate $\hat{b}_i$ is meaningless to us.

Since the model parameter b_i obeys the following normal distribution: $\hat{b}_i \sim N\left(b_i, \sigma^2 c_{ii}\right)$, where c_{ii} denotes the i th element on the main diagonal of the matrix $(X'X)-1$, and σ^2 is the variance of the random error term, it is replaced by its estimator in the actual calculation:

$$\hat{\sigma}^2 = \frac{\sum \varepsilon_i^2}{n-k-1} = \frac{\varepsilon'\varepsilon}{n-k-1} \tag{10}$$

A statistic can be constructed as follows:

$$t = \frac{\hat{b}_i - b_i}{S_{\hat{b}_1}} = \frac{\hat{b}_i - b_i}{\sqrt{c_{ii}\dfrac{\varepsilon'\varepsilon}{n-k-1}}} \tag{11}$$

Given a significance level of α, a critical value of $t_{a/2}(n-k-1)$ is obtained, whereupon the original hypothesis can be rejected or accepted on the basis of: $|t| > t_{a/2}(n-k-1)$ or $|t| \le t_{\alpha/2}(n-k-1)$, thus determining whether the corresponding explanatory variables should be included in the model.

3 Findings and Analysis

It is known that in the research design, this paper takes two first-year classes of Business English majors in a university as the research subjects, and sets up experimental and control classes to carry out computer-assisted teaching practice. The experimental class conducts an experimental study on applying metacognitive strategies during practice, while the control class maintains the regular teaching method for professional learning. In this chapter, the results of the teaching practice study in this paper will be analyzed in depth using the data processing and multiple regression prediction method proposed in this paper.

3.1 Metacognitive level analysis

3.1.1 Pre- and post-test comparisons of metacognitive level dimensions

The results of the test set of the dimensions of metacognitive level of the students in the experimental class before and after conducting the teaching practice are specifically shown in Table 2. As can be seen from the table, there are significant differences in metacognitive knowledge (P=0.005<0.01), metacognitive monitoring (P=0.003<0.01), and metacognitive experience (P=0.012<0.05) before and after the students received metacognitive strategy instruction. In terms of the total metacognitive score, the posttest score of the experimental class was as high as 141.83, which was an increase of 47.81 compared to the pre-test, showing a significant difference (P=0.007<0.01). The metacognitive abilities of the students in the experimental class were more or less improved, indicating that the implementation of computer-assisted instruction with metacognitive strategies was effective and to a certain extent did improve the metacognitive level of the students in terms of learning.

Table 2. Dimensions of metacognitive level

Dimension	Testing	Mean	Standard deviation	P
Metacognitive knowledge	Before experiment	35.61	0.8	0.005
	After experiment	49.45	1.01	
Metacognitive monitoring	Before experiment	38.68	0.8	0.003
	After experiment	66.23	0.8	
Metacognitive experience	Before experiment	19.73	0.94	0.012
	After experiment	26.15	0.81	
Meta-cognitive score	Before experiment	94.02	0.77	0.007
	After experiment	141.83	0.87	

3.1.2 Metacognitive level pre- and post-test comparisons across questions

Before and after the practice of applying metacognitive strategies in computer-assisted teaching, the Questionnaire on the Application of Metacognitive Strategies was distributed to the students in the experimental class to count the scores of each specific topic in the three sub-strategies of planning strategy, monitoring strategy, and evaluation strategy. The results of the pre- and post-test comparisons of the experimental class students' metacognitive level for each topic are specifically shown in Figure 3. As can be seen from the figure, overall, the metacognitive level of the experimental class students has improved in all dimensions of each item. Students' awareness of their own learning level and their knowledge of the subject of study has improved. Among them, the metacognitive monitoring improved more, the scores of the five topics from B1 to B5 improved by 1.614 compared with the pre-test on average, while the metacognitive planning and metacognitive evaluation improved by 0.952 and 1.444 on average.Obviously, after the teaching practice, the experimental class students' ability to plan, monitor and evaluate their learning in various aspects has been significantly improved with the help of metacognitive strategies.

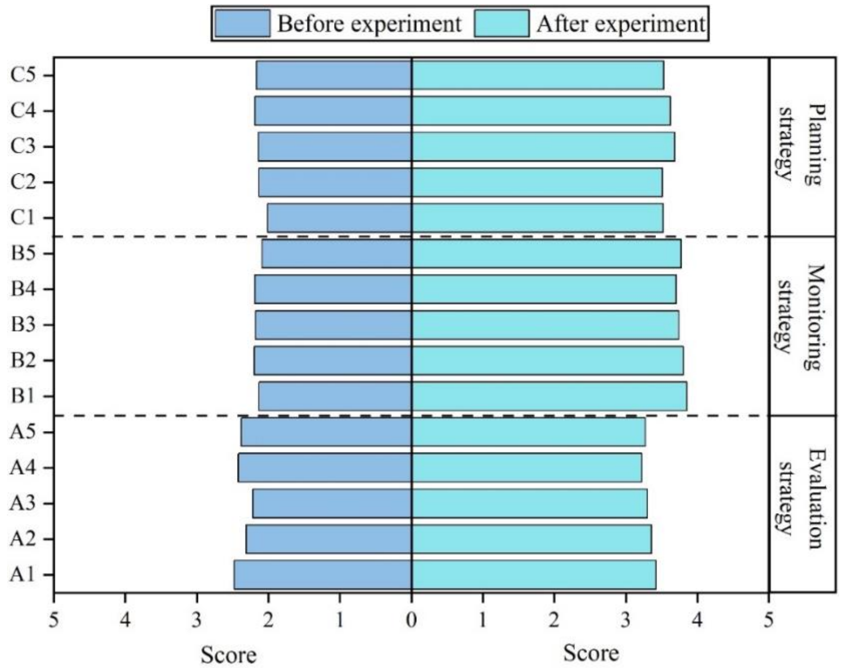

Figure 3. Questionnaire score

3.2 Correlation and multiple regression analysis

This section examines whether there is a correlation between metacognitive strategies in computer-assisted instruction and with learning effectiveness by employing the correlation analysis methodology and multiple linear regression modeling proposed in this paper with the help of Pearson's correlation analysis in SPSS 26.0.

3.2.1 Correlation analysis between metacognitive strategies and learning effectiveness

The correlation analysis between metacognitive strategies and learning effectiveness is shown in Figure 4. In this paper, we simplified the data in the figure and only kept the correlation coefficient, if the correlation coefficient with "**", it means $p<0.01$, there is a correlation between the two and the correlation is significant, if the correlation coefficient does not have "**", it indicates that $p>0.05$, and there is no correlation between the two. As can be seen from the figure, the three subcategories of metacognitive strategies, statistical planning strategies, monitoring strategies, and evaluation strategies, are positively correlated with learning effectiveness. The results show that the correlation between students' metacognitive strategies and learning effectiveness reaches a highly significant level, i.e., the use of metacognitive strategies has a positive effect on students' learning effectiveness, where the correlation between total metacognitive strategies and the three subclasses of statistical planning strategies, monitoring strategies, and evaluating strategies are the highest, 0.922**, 0.962**, and 0.968**, respectively. The above analysis shows that metacognitive strategies have a significant effect on improving students' learning effectiveness and that improving students' learning effectiveness in computer-assisted instruction starts with total metacognitive strategies so as to have the maximum effect.

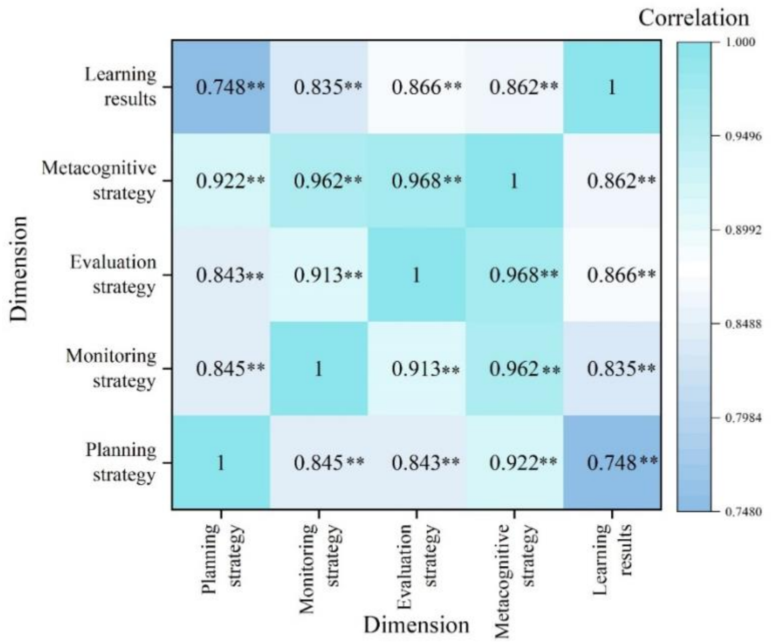

Figure 4. Correlation between metacognitive strategies and learning outcomes

3.2.2 Analysis of the impact of metacognitive strategies on learning effectiveness

In this section, the impact of metacognitive strategies on students' learning effectiveness will be explored using the multiple linear regression model proposed in this paper. Before conducting the multiple linear regression, it is first necessary to determine whether the learning effectiveness of the 63 students in the experimental class who participated in this metacognitive strategy application practice conforms to a normal distribution. The histogram of learning effectiveness of the experimental class students is shown in Figure 5. It can be seen that a normal curve is shown in the histogram, indicating that the learning effectiveness basically obeys a normal distribution, and its mean value is 119.14 with a standard deviation of 28.163, indicating that the sample is representative.

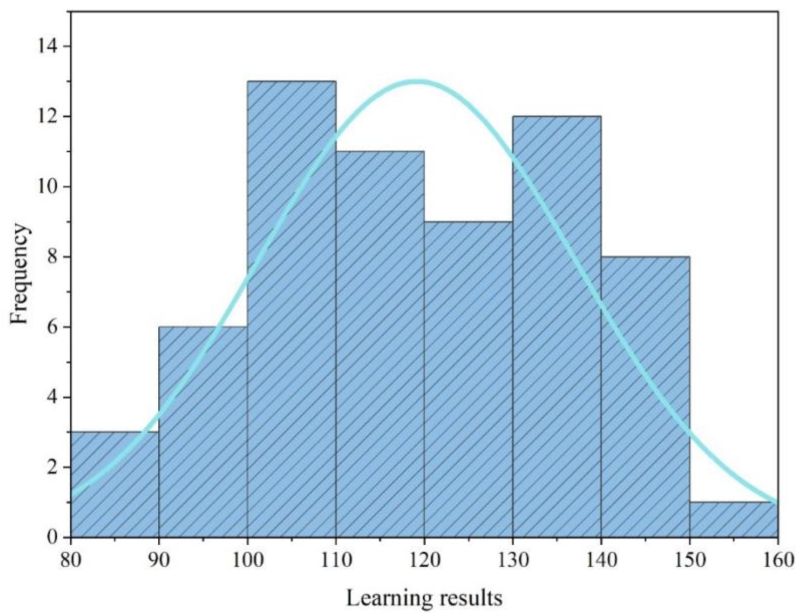

Figure 5. Histogram

The normal P-P plot of the learning effectiveness of the students in the experimental class is shown in Figure 6. In the graph, all scatter points are distributed near the diagonal line, which means that all sample data are approximately normally distributed. Therefore, from the histogram and the normal P-P plot, it can be seen that the learning effectiveness of the students in the experimental class conforms to a normal distribution, which in turn allows us to analyze the effect of metacognitive strategies on learning effectiveness.

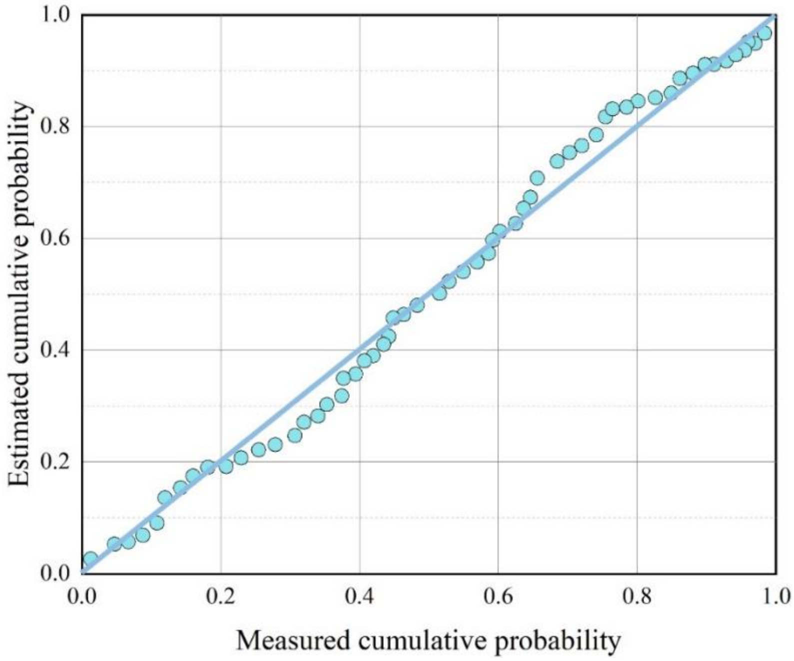

Figure 6. Normal p-p diagram

In the multivariate linear regression analysis stage, this paper begins with a goodness-of-fit analysis. The model summary table demonstrating the goodness of fit of this multiple linear regression simulation is shown in Table 3. The goodness-of-fit $R^2 = 0.826$ means that the independent variables of planning strategy, monitoring strategy, and evaluation strategy can explain a total of 82.6% of the variation of the dependent variable, i.e., 82.6% of the dependent variable "students' learning effectiveness" is affected by the above factors. Generally speaking, a fit of more than 50% can be considered as a good fit for a model.

Table 3. Model summary table

Model	R	R^2	Adjusted R^2	Standard error
1	0.905a	0.826	0.802	17.568

The significance of the regression model was then examined using the results of the ANOVA table operations as shown in Table 4. The significance of the regression model indicates whether the existence of the regression model is meaningful. If none of the three subcategories of the independent variable metacognitive strategies, planning strategies, monitoring strategies, and evaluation strategies, significantly affects the dependent variable "student learning effectiveness", it means that the existence of this regression model is meaningless. As shown in the table, $F=55.144$, $P=0.003<0.05$, it is said that the regression model is significant, i.e., at least one of the multiple independent variables in the model can significantly affect the dependent variable "student learning effectiveness".

Table 4. ANOVA

Model	Sum of squares	Degree	Mean square	F	Significance
Regression	156680.8	10	17623.33	55.144	0.003^b
Residual error	35320.12	112	322.781		
Total	192000.9	123	-		

Finally, the multiple linear regression analysis was performed and the linear regression coefficients are shown in Table 5. Since all VIFs are <10, there is no multicollinearity between the independent variables, which means that the results of this operation are accurate and reliable. The results of the multiple linear regression analysis provide the regression coefficients of the linear regression model, when the Beta coefficient is positive and satisfies the significance <0.05 are evaluation strategy (Beta=0.415, p=0.002), monitoring strategy (Beta=0.147, p=0.006), and planning strategy (Beta=0.106, p=0.004). In other words, evaluation strategy, monitoring strategy and assessment strategy of metacognitive strategies are positive predictors of students' learning effectiveness.The higher the absolute value of Beta, the more predictive it is for students' learning effectiveness. Among them, the order of Beta value is Evaluation strategy>Monitoring strategy>Planning strategy, which indicates that the evaluation strategy of metacognitive strategies is the strongest predictor of students' learning effectiveness, which means that the higher the students' ability to evaluate their own learning, the higher their learning effectiveness will be.

Table 5. Linear regression coefficient

Model	Unnormalized coefficient		Normalization factor	t	Significance	Common linear statistics	
	B	Standard error	Beta			Tolerance	VIF
(constant)	52.015	13.564	-	3.912	0	-	-
Planning strategy	0.952	4.956	0.106	0.185	0.004	0.252	4.722
Monitoring strategy	6.237	5.18	0.147	1.172	0.006	0.146	7.382
Evaluation strategy	17.524	5.316	0.415	3.388	0.002	0.142	8.757

4 Conclusion

In this paper, correlation analysis and multiple regression modeling are used as data processing and analysis tools to formulate the research object and research subjects to carry out the practice of metacognitive strategy application in computer-assisted teaching. The metacognitive level of the students in the experimental class before and after the experiment was analyzed, and the students in the experimental class showed significant differences in the sub-strategy dimensions of metacognitive strategy, metacognitive knowledge, metacognitive monitoring, and metacognitive experience (P<0.05), and the total score of metacognition increased by 47.81 compared to the pre-experiment and likewise demonstrated significant differences (P=0.007<0.01). Among the scores of each question on the questionnaire, the experimental class showed an average increase of 0.952, 1.614, and 1.444 in the scores of the questions on planning strategy, monitoring strategy, and evaluation strategy after the experiment.The analysis was carried out to analyze the correlation between the metacognitive strategies and the students' learning effectiveness, and the correlation between the total metacognitive strategies and the three subclasses of statistics on planning strategy, monitoring strategy, and evaluation strategy was 0.922**, 0.962**, and 0.968**, which proved that there was a significant difference between the total metacognitive strategies and the three subclasses, 0.968**, proving that metacognitive strategies have a significant effect on improving students' learning effectiveness. Using the multiple linear regression model in this paper, the effect of metacognitive strategies on learning effectiveness was validated and analyzed. In the linear regression results, the Beta coefficients of evaluation strategy, monitoring strategy and planning strategy are positive, which are 0.415, 0.147 and 0.106, respectively, and among them, the evaluation strategy has the highest Beta value, which proves that it is the strongest predictor of students' learning effectiveness.

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