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Enhancing Core Competencies in Mathematics through Project-Based Learning

-- A Study on the Relationship between Creative Thinking and Mathematical Abstraction Ability

Nanxi Xu, Jian Xu, Lu Xu*

School of Artificial Intelligence, Jianghan University, Wuhan, Hubei 430056

Abstract: This paper examines the relationship between creative thinking and mathematical abstraction ability, using a sample of 210 middle school mathematics test papers. Employing SPSS software for correlation and regression analysis, the study analyzes and compares these two competencies. The results indicate a significant positive correlation between mathematical abstraction ability and creative thinking in mathematics. This finding suggests that project-based learning can effectively enhance students' core competencies in the mathematics subject area.

Keywords: Creative thinking; Mathematical abstract ability; Project-based learning; Mathematics core literacy

1. Introduction

Project-based Learning (PBL) is a dynamic educational approach. This process fosters a deeper understanding of knowledge and skills, enhancing students' creativity, teamwork, hands-on capabilities, and project execution skills. These standards emphasize that, at the middle school level, mathematics should be taught through project-based methods to cultivate core competencies in students.

Mathematical abstraction is the competency of deriving mathematical objects of study through the abstraction of quantitative relationships and spatial forms. It is one of the core competencies in the field of mathematics.

Creative thinking is a complex cognitive activity. Guilford posited that creativity consists of creative thinking and a creative personality, with creative thinking being the core, primarily manifesting as divergent thinking characterized by originality, flexibility, and fluency. Creativity, widely recognized as the external expression of creative thinking[1], in this paper, refers to the dimensions of fluency, originality, and flexibility manifested in the process of solving mathematical problems.

From the perspective of the manifestations of core competencies in mathematics, Professor Yu Ping identified three forms of learning mathematics: understanding knowledge, transferring knowledge, and innovating knowledge[2]. These forms lead to different levels of core competencies, categorizing them into understanding, transferring, and innovating.

International research on mathematical abstraction began in the 1980s. For instance, Jee Yun Hong & Min Kyeong Kim categorized mathematical abstraction into three levels[3]: recognizing perceptual abstract mathematical structures, applying internalized mathematical structures, and constructing new mathematical structures through internalization.

In evaluating students' mathematical abstraction, international scholars emphasize the significance of numbers and shapes in abstraction and use tests or questionnaires to evaluate students' levels[4].

Regarding the assessment of creative thinking in mathematics, international methods are varied[5], but the approach based on Guilford's concept of divergent thinking[6]—characterized by fluency, originality, and flexibility—is widely accepted. The Torrance Tests of Creative Thinking (TTCT) are commonly used for this purpose[7].

2. Study design

2.1 Object of study

The subjects of this study were first-year middle school students from two schools in Wuhan, Hubei Province, labeled School A and School B. The study involved five different classes, totaling 215 students.

2.2 Data collection

This study primarily employed survey methods using test papers, designed according to the various forms of mathematical abstraction ability and the different dimensions of evaluating mathematical creative thinking. Uniform scoring standards were established to gather corresponding student data, which were then entered into software like SPSS and Excel for analysis.

2.3 Research method

The theoretical basis of this study is grounded in Piaget's theory of cognitive development, and the framework for level classification is based on the three-tier index system for evaluating core competencies constructed by Professor Yu Ping. The study utilizes a one-way ANOVA to compare factors affecting the differences across the three dimensions and levels. Pearson correlation analysis is then employed to examine the relationship between creative thinking and mathematical abstraction abilities in middle school students. Finally, linear regression is used to quantify the relationships between creative thinking and the three levels of mathematical abstraction ability, as well as between mathematical abstraction ability and the three dimensions of creative thinking. All analyses were conducted using SPSS 26.0 software.

3. Data analysis

3.1 Reliability and validity of Test Paper

In this questionnaire survey, a total of 215 test volumes were issued, and 210 were effectively recovered, with an effective recovery rate of 97.7%. After recovering the test volumes, and the data obtained were input into SPSS for analysis. The Klonbach coefficient of mathematical abstraction ability was 0.888, and the KMO sample appropriateness measure was 0.896. It can be seen from the data that the structural validity of this test volume is also good.

3.2 Mathematical abstract ability data statistical analysis

This test is out of (9+9+13=31) points, and the total score of mathematical abstraction ability of the 210 students tested follows a normal distribution with a standard deviation of 5.112.

3.3 Mathematical creative thinking data analysis

In order to understand the students' overall ability of creative thinking in mathematics, the author analyzes the overall score of the test paper. The test paper full score of the paper is 64 points. The result shows, the average score is 30.20, and the passing score of the paper is 38.4, which indicates that the overall score is not ideal, the overall score of students' creative thinking in mathematics conforms to the normal distribution with a standard deviation of 7.879.

3.4 Analysis of the correlation between Mathematical Abstract Ability and Mathematical Creative Thinking

As to whether there is a correlation between mathematical abstract ability and mathematical creative thinking and whether the correlation is significant, SPSS software is used to analyze the two overall results.

As can be seen from the above statistics analysis, $r=0.839$, $P=0.000 < 0.005$, it can be seen that mathematical abstract ability is significantly positively correlated with the existence of mathematical creative thinking, and the correlation coefficient is 0.839. Therefore, it can be considered that there is a high correlation between mathematical abstraction and mathematical creative thinking in junior middle school mathematics.

Spearman correlation analysis result shows mathematical abstract ability is significantly positively correlated with the three dimensions of mathematical creative thinking. This also shows that the improvement of students' mathematical creative thinking can well enhance students' mathematical abstract ability, so in teaching, we should pay attention to cultivating students' thinking fluency, flexibility and originality. In other words, project-based learning can improve the core literacy of mathematics.

After the correlation analysis, taking mathematical abstract ability as independent variable, we carry out regression analysis on mathematical abstract ability and mathematical creative thinking, in order to further clarify the relationship between them. First, the scatterplot is used to observe whether there is a linear relationship between the two. We find, mathematical abstract ability and mathematical creative thinking are generally linear, indicating that with the improvement of mathematical abstract ability, mathematical creative thinking is also improving.

ANOVAa is an abstract table of analysis of variance, in which the variance F value is 495.496 and the significance P value is 0.000b, which is less than 0.05, indicating that the explanatory variance of this regression model reaches the significance level and has statistical significance.

The result shows the significance test of the coefficients. The regression equation obtained without standardized coefficient is as follows: score of mathematical creative thinking =5.687+1.303× score of mathematical abstract ability. The regression equation after the standardized coefficient is as follows: score of mathematical creative thinking =0.839× score of mathematical abstract ability. It can be seen that mathematical abstract ability has a very important positive effect on mathematical creative thinking.

Regression analysis of three forms of mathematical abstract ability and mathematical creative thinking.

Results show that the F value of variance is 165.008 and the P value of significance is 0.000b, which is less than 0.05, indicating that the explanatory variance of this regression model reaches the level of significance by ANOVA.

As can be seen from statistics, under the premise of no standardized coefficient, the score of mathematical creative thinking =6.234+1.141× score of expression 1 +1.094× score of expression 2 +1.563× score of expression 3. The regression equation after standardization is as follows: math creative thinking score =0.221× expression1 score +0.260× expression 2 score +0.463× expression 3 score. It can be seen that the three forms of expression have a positive effect on mathematical creative thinking, and the significance P-value of the three independent variables is 0.000, reaching a significant level.

4. Conclusion and suggestion

4.1 Present situation of Mathematical Abstract Ability

On the whole, the first grade students' mathematical abstract ability is at the average level. It also means that students' ability to draw patterns from complex situations and generalize them has yet to be improved.

4.2 Research on the relationship between Mathematical Abstract Ability and Mathematical Creative Thinking

It can be seen that there is a significant positive correlation between mathematical abstract ability and mathematical creative thinking. The standardized regression equation is $y=0.221x1 +0.260x2 +0.463x3$.

4.3 Some Suggestions on developing students' Mathematical Abstract Ability and Creative Thinking

(1) Pay attention to learning and reflection, and cultivate abstract thinking and criticism

(2) Increase information means and adopt diversified teaching designs

(3) Create a creative atmosphere and improve innovation awareness

(4) Focus on problem-driven, and actively carry out project-based learning

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