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ANALYSIS OF THE MATHEMATICAL MODELING ABILITY FOR SENIOR SCHOOL STUDENTS

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Abstract

Mathematical modelling ability is one of the important core qualities of mathematics, and its development tends to be affected by non-intelligence factors. To understand the relationship between motivation, emotion, will, attitude and character of senior school students and mathematical modelling ability, this paper conducts a survey of 202 students in two senior schools. The derived findings reveal that the non-intelligence factors of senior school students are generally at the "medium" level and are of a significant correlation with mathematical modelling ability. Some suggestions are provided to stimulate their learning motivation of mathematical modelling so that students can produce good emotions to regulate and maintain their long-term learning activities of mathematical modelling.

Keywords: *Mathematical modeling; Correlation; Regression; Senior school;*

Introduction

Mathematical modelling has been introduced into Chinese schools for decades of years and is popular in many universities. However, in most senior schools, the process of teaching implementation of mathematical modelling has not been fully integrated into the instruction activities. More curriculum of mathematical modelling appeared in the extracurricular practical activities. Only a few, instead of all, students are chosen to be taught the related mathematical modelling knowledge, resulting in the limited development of the mathematical modelling instruction in senior schools. In addition, many instructors in the middle school do have not a thorough understanding of the modelling instruction and they lack systematic modelling strategies to guide modelling teaching activities.

The mathematical curriculum standard for senior schools of China (Ministry of Education, PRC, 2020) states that mathematical modelling is the quality of abstracting real problems, expressing problems with mathematical language and building models with mathematical methods to solve real problems. The process of mathematical modelling mainly includes the following aspects: involvement in the actual situation, link to the mathematical concepts, presentation of the problems, analysis of the problems, the establishment of the models, determination of related parameters, calculation of the solutions, validation of the obtained results and the improvement of models (Houston, 2007).

Many factors influence the mathematical modelling ability of senior school students. Although the intelligence and experience of mathematical modelling activities are important, other factors from the personal and emotional aspects such as motivation, attitude, belief and will also play an indispensable role in learning, regulation and maintaining modelling activities. This paper will mainly explore the correlation between the personal factors (motivation, emotion, attitude, will

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and character) and the mathematical modelling ability of senior school students and provide senior school students with some suggestions for cultivating their mathematical modelling ability.

Research Methodology

Research objects

In this investigation, we hand out 217 questionnaires to students in two senior schools in Zhuzhou City of Hunan Province and 202 valid questionnaires (112 boys and 90 girls) were collected, with an effective rate of 93.09%. The test was conducted in the classroom and the response time is 15 minutes. Excel and SPSS 22.0 were employed to record the collected data and implement the correlation analysis and the regression analysis.

Study tool

The main source of the questions arises from the questionnaire "learning motivation strategy questionnaire" ,which includes external driver, internal driver, task value, belief regulation, self-efficacy, test anxiety etc. Especially, questions on the motivation are borrowed from the internal driver and external driver test groups (Pintrich et.al, 1993). In addition, some items in the questionnaire are revised ones from the "Achievement Motivation Scale for Middle School Students" (Garcia & Mc Keachie, 2003), "Mathematics Anxiety Rating Scale" (Richardson & Suinn 1972), etc. Finally, we get the scale which includes five main dimensions of motivation, emotion, attitude, will, character.

There are 75 questions in the questionnaire, which are graded by Likert five grades (Preedy & Watson, 2010). One can get 5 points, 4 points, 3 points, 2 points and 1 point according to the corresponding options: very consistent, consistent, basically consistent, inconsistent and very inconsistent. The “Total” represents the total score while M, E, A, W and C are the scores of motivation, emotion, attitude, will and character five dimensions respectively. Table 1 describes the five grades of the obtained scores. For example, if the subject's score in the factor “Motivation” is 30, then it is judged that the subject's motivation is in the "Low" level. If the total score of a tested subject is 240, then the grade of the subject is judged to be in the "Medium" level.

Table 1 *Five grades of the scores*

	Grade				
	Low	Below Medium	Medium	Above Medium	Excelent
M	⩽50	[51, 60]	[61, 70]	[71, 85]	⩾86
E	⩽48	[49, 61]	[62, 74]	[75, 88]	⩾89
A	⩽45	[46, 55]	[56, 66]	[67, 79]	⩾80
W	⩽22	[23, 28]	[29, 36]	[37, 45]	⩾46
C	⩽25	[26, 32]	[33, 38]	[39, 46]	⩾47
Total	⩽190	[191, 236]	[237, 284]	[285, 343]	⩾344

Data pre-processing and described statistics

To avoid the reliability differences generated by the sample differences, we used the questionnaire to test a small sample before the formal implementation of the test. There are 48 freshmen (just graduated from the senior school) in the Hunan University of Technology participate in this investigation. The obtained Cronbach’ α coefficient (Cronbach et.al, 1965) is 0.813, indicating that the questionnaire has high reliability, validity and rationality.

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The distribution of 202 investigated students among five levels is described in Table 2. It can be seen that the number of students whose personality factors are at the "medium" level is the most, altogether 122 students, accounting for 60.4%; There were 55 and 15 students whose personality factors were at the "upper-medium" and the “low-medium” level, accounting for 27.2% and 7.4%; Only 1.9% of the personality factors reached the "excellent" level.

Table 2 *Distribution of the number of students*

	Grade				
	Low	Below Medium	Medium	Above Medium	Excellent
Total	6	15	122	55	4

The statistics of the extreme and the average scores among 202 students are listed in Table 3. The minimum values of the motivation, emotion, attitude, will and personality factors are 93, 91, 84, 48 and 50, while the maximum values are 41, 36, 38, 13 and 20, respectively.

Table 3 *Statistics of the extreme and the average scores*

	Minimal Value	Maximal Value	Average
M	41	72	61.3
E	36	91	64.2
A	38	84	66.1
W	13	48	28.5
C	20	43	33.2
Total	148	338	243.5

From the column of the maximum value, motivation and character include students of "Above Medium" level, but not those with "Excellent" level. Moreover, the average value of the total level of all factors is 243.5, indicating that the personality factors of all students in senior school are generally at the "Medium" level according to Table 2.

Results Analysis and Discussion

Correlation analysis between five factors and the mathematical modeling ability

We first made a correlation analysis between 5 factors and the mathematical modelling ability and the obtained results were listed in Table 4. It can be seen that the correlation coefficient between five factors and the mathematical modelling ability of senior school students is 0.701, and the probability value of the two-sided test is 0.000, less than 0.001, implying a highly positive correlation between 5 factors and the mathematical modelling ability. Moreover, each factor is also positively correlated to the modelling ability with the respective coefficient being 0.685, 0.734, 0.624, 0.536 and 0.632. The largest and the smallest correlation coefficients appear in the factors “Emotion” and “Will”, respectively.

Table 4 *Correlation analysis*

	Modeling Ability	Sig (two-sided).
5 Factors	0.701	0.000**
M	0.685	0.000**
E	0.734	0.000**
A	0.624	0.000**
W	0.536	0.000**

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C	0.632	0.000**

**: significant

Uni-variable linear regression analysis of 5 factors and mathematical modeling ability

We next utilize SPSS 22.0 to conduct uni-variable linear regression analysis. The independent variable was the 5 factors and the dependent variable was mathematical modelling ability. The analysis results are shown in Table 5, where R square stands for the degree of fitting, and the value range is from 0 to 1. The closer the value is to 1, the higher the degree of the fitting is.

Table 5 *Linear regression analysis of 5 factors and mathematical modeling ability*

R	R square	Adj. R square	Std. Err.	Durbin-Watson
0.875	0.765	0.776	0.453	1.523

It follows from Table 5 that the value of the R square is 0.765, showing that 76.5% of the mathematical modelling ability of the investigated students in senior schools is caused by 5 factors. We further ran SPSS to implement the analysis of variance for the modelling ability and the derived results are given in Table 6.

Table 6 *ANOVA for modeling ability*

	ANOVA				
	Square	df	Mean Square	F	Sig
Reg.	186.34	1	186.34	374.93	0.000**
Res.	99.45	200	0.497		
Tot.	285.79	201			

Table 6 shows that the value of F is 374.93. and the calculated “Sig.” is 0.000, less than 0.001, meaning that the regression is significant and the fitting effect of the equation is good. So the linear regression well describes the relationship between 5 factors and the mathematical modeling ability.

To elaborate on the concrete regression equation, we summarize the computed coefficients and the error in Table 7. It can be seen that the constant is – 4.673, and the regression coefficient of the five factors is 0.032. Then the linear regression equation is

$$Y = 0.032X - 4.673.$$

Both of the significance probabilities are less than 0.05, implying that the regress equation is of statistical significance.

Table 7 *Coefficients in linear regression for the modeling ability*

	Non-standard		Standard Coef.	t	Sig
	Coefficient	Error			
Constant	-4.673	0.266		-17.562	0.000
5 factors	0.032	0.002	0.878	27.432	0.000

Multiple linear regression analysis of five factors and the mathematical modeling ability

We finally take five factors and the modelling ability as independent and dependent variables to conduct the multiple linear regression analysis. The derived results are shown in Table 8, which shows the value of R square is 0.618, i.e. the 61.8% of the mathematical modelling ability can be interpreted by these 5 factors. It also can be seen from Table 8 that the adjusted value of the R

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square is 0.625, indicating that the multiple regression equation fits well.

Table 8 *Distribution of the number of students*

R	R square	Adj. R square	Std. Err.	Durbin-Watson
0.786	0.618	0.625	0.501	1.674

Analogously, we conduct the analysis of the variance of the multiple linear regression in Table 9, which shows the value of the F is 67.03 and Sig is 0.000, less than 0.001. Therefore, the fitting effect of the equation is good and the regression equation has good representativeness.

Table 9 *ANOVA for modeling ability*

	ANOVA				
	Square	df	Mean Square	F	Sig
Reg.	176.65	5	35.33	67.03	0.000**
Res.	103.86	197	0.527		
Total	280.51	202			

To describe the relation of the mathematical modelling ability and the 5 different factors, we list the regressed coefficients in Table 10. One can see that the significance probability of constant is 0.029 and the significance probabilities of the other 5 factors are all less than 0.05. So the regression equation is of statistical significance.

Table 10 *Coefficients in multiple linear regression for the modeling ability*

	Non-standard		Standard Coefficients	t	Sig
	Coefficient	Error			
Constant	0.431	0.184		2.342	0.029**
M	0.245	0.045	0.214	5.444	0.000**
E	0.363	0.046	0.323	7.891	0.000**
A	0.267	0.031	0.245	8.612	0.000**
W	0.198	0.023	0.145	8.608	0.000**
C	0.321	0.041	0.284	7.829	0.000**

Moreover, if denote the motivation, emotion, attitude, will and character by X1, X2, X3, X4 and X5, respectively, the multiple regression equation between five independent variables and mathematical modelling ability is of the following form

$$Y = 0.245X_1 + 0.363X_2 + 0.267X_3 + 0.198X_4 + 0.321X_5 + 0.431.$$

By regarding 5 factors as an independent variable, One can see from the regression analysis that it interprets 76.5% variation of mathematical modelling ability. On the other hand, it follows from Table 8 that five factors in multiple regression explain 61.8% variation of mathematical modelling ability. The Durbin-Watson values in Table 5 (1.523) and Table 8 (1.674) indicate that the residuals are relatively independent and the previous estimates of the regression model and the drawn conclusions are reliable.

Conclusion and Suggestions

1. From the previous analysis, one can see that the five factors of most senior school students are at the "medium" level, and few students reach the "excellent" level. Concretely, the students' attitude to mathematical modelling is relatively stronger and the motivation dimension is relatively weaker. The higher average score of attitude indicates that students have a positive attitude towards mathematical modelling learning. The lower average score of the motivation dimension exhibits a

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relatively weak desire for mathematical modelling. Possible reasons may come from the learning requirements and the studying difficulty. Much content and fast pace in mathematical study may bring great pressure to students, resulting in low learning motivation in mathematical modelling. In addition, the content of mathematical modelling is more abstract and difficult to understand, making students feel boring and difficult to get a sense of achievement.

2. There is a significant correlation between five factors and the mathematical modelling ability. From the correlation analysis, the correlation coefficient between five personal factors of senior school students and mathematical modelling ability is 0.701, revealing a significant correlation. Moreover, five factors can be ordered from the strong degree to the weak degree as “Emotion”, “Motivation”, “Character”, “Attitude” and “Will”. Regression analysis shows that each factor has a certain impact on mathematical modelling ability. From the regression coefficient, “Character” has a greater impact on senior school students' mathematical modelling ability, while “Will” has a smaller impact on their mathematical modelling ability.

According to the above findings, some suggestions and measures can be taken to help students in the senior school develop mathematical modelling abilities.

● *Choice of appropriate learning materials for students*

As the carrier of teaching and learning, the textbook may have a direct impact on the learning effect of mathematical modelling. In addition, students' attitude, confidence, interest and motivation in mathematical modelling will affect their performance and achievement to a certain extent. Therefore, in addition to the basic knowledge in textbooks, instructors are supposed to select mathematical modelling materials according to the learning situation and stimulate them to actively participate in mathematical modelling activities. The design of mathematical modelling problems should be consistent with the objectives and requirements of the new curriculum, combined with the situation of students.

● *Diversification of teaching mode*

The instruction form of mathematical modelling is diversified. Although it is not possible to set up a mathematical modelling course alone due to the heavy learning tasks in senior school, some extracurricular activities might be interspersed with the content of mathematical modelling. At the same time, the students' subjective consciousness of modelling learning should be strengthened to make them more active in mathematical modelling. At the same time, the instruction of modelling software should be up to date. Instructors are suggested learning and improving the operating ability of related modelling software such as Excel, MATLAB and LINGO. Meanwhile, instructors may encourage students to learn skills of data analysis, processing and modelling by themselves, so that students can get more comprehensive development in mathematical modelling.

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