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Analysis on the Influencing Factors of Promotion of Academic Achievement in High School Mathematics

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Abstract

As the connecting stage of compulsory education and higher education, high school plays an irreplaceable role in the construction of talent power. Mathematics achievement can directly reflect the overall learning situation of students, and it is an important embodiment of the quality of school education. In this paper, we focus on mining the potential factors affecting the quality of high school learning with mathematics academic achievement as the study object, in order to achieve the overall improvement of the quality of high school education. This paper introduces SCAD penalty into forward continuation ratio model, and proposes a new method to select factors influencing the improvement of academic achievement. The study results show that students' gender, grade and class level have no significant impact on the improvement of academic achievement. The focus in class, regular extracurricular exercises, mathematics learning methods and strategies, and the skills of solving problems have positive effects on the improvement of students' mathematics academic achievement, while the mathematics learning anxiety will have a negative inhibitory effect. Therefore, the key to the improvement of academic achievement lies in students' classroom and extracurricular learning state.

Keywords: academic achievement, influencing factors, ordinal response variable, continuation ratio models, SCAD penalty

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1. Introduction

The report of the 20th National Congress of the Communist Party of China emphasized that education, science and technology, and human resources are the basic and strategic support for the comprehensive construction of a modern socialist country. Accelerating the construction of a high-quality education system is a new requirement for Chinese education in the new era. In 2017, the Ministry of Education and four other departments issued the Plan for the Popularization of Upper Secondary Education (2017-2020), which puts improving the quality of education in a prominent position, proposing to enhance the appropriateness and attractiveness of upper secondary education, and laying the foundation for students' growth and success. Academic achievement, as an important indicator reflecting the quality of school education and the development of students, can reflect the learning effect obtained within a relatively precise and limited scope, and can also portray the level of knowledge and skills acquired through certain teaching and training (Zheng 1987). The analysis of influencing factors is the key research content of academic achievement, which mainly includes four aspects: students, families, teachers and schools (An and Yang 2018; Li *et al*. 2018; Gong 2019; Wang *et al*. 2018). Among them, the majority of studies have explored the influencing factors of academic achievement and their mechanisms from the perspectives of students' learning inputs such as learning strategies, learning attitudes and learning emotions. Alexander Astin (Alexander 1985), one of the earliest scholars to study the relationship between learning inputs and academic achievement, pointed out that the quality and quantity of learning inputs have a direct correlation with students' learning gains and development. Numerous studies have shown that effective learning inputs in early childhood, adolescence, and adulthood all positively contribute to academic achievement (Furrer and Skinner 2003; Jiang 2019; Su 2020). However, the same type and intensity of input is likely to result in different achievements in different subjects and at different stages of learning, and therefore subject and stage differences need to be taken into account when examining the impact of learning input on academic achievement.

The senior education stage is the golden period for students' independent development and personality formation. The evaluation and monitoring of the academic achievements in high school mathematics are not only related to the improvement of their overall academic level, but also to the development of various kinds of thinking and abilities, as well as the choice of their future career. However, starting from specific subjects and learning stages, combining different subject characteristics and specific learning stages to conduct targeted and systematic research, and fully exploring the key factors influencing the improvement of academic achievement in high

school mathematics, in order to find the focus point of learning input is an important issue neglected by the current research.

At present, most studies on academic achievement take academic score as an indicator to measure, and some scholars analyze academic score as a continuous variable, such as Yan and Tian (2020), Tan *et al*. (2016). In order to be more conducive to the study of the hierarchy of students' academic achievement levels, other scholars have discretized academic achievement and treated it as a categorical variable, such as Ding and Wang (2017). However, the levels of academic score are characterized by the order of high and low grades, which is an ordinal variable, and treating it as an unordered categorical variable cannot may lead to bias of the results.

In this paper, we focus on the core influencing factors of academic achievement in high school mathematics, make full use of the order information of the academic achievement level, take the academic achievement as an ordinal response variable, construct the forward continuous ratio model (O'Connell 2006), and propose the variable selected method of forward continuous ratio model based on SCAD penalty for the first time. In this paper, the SCAD penalty method is utilized to obtain more accurate and stable results in the regression analysis of large-scale data. In this paper, we use the SCAD penalty to find out important factors that really promote the academic achievement of high school mathematics and to provide more direct references and bases for the improvement of the students' learning effects and the improvement of the quality of school education.

2. Methodology

2.1 Sample

This study takes students from grade one to grade three of senior school in Jiangsu Province as the object. A total of 435 questionnaires were returned, 18 invalid questionnaires were excluded, and the final valid questionnaires totaled 417. The basic information of the sample is shown in Table 1.

Table 1 Basic information about the study subjects

variate	attribute	number of people	percentage
gender	male	225	54.0%
	female	192	46.0%
grade	Senior one	210	50.4%
	Senior two	102	24.5%
	Senior three	105	25.2%
class level	ordinary class	207	49.6%
	intensive class	210	50.4%

2.2 Data collection tools

The data used in this paper are from the questionnaire survey of high school students' involvement in mathematics learning conducted by our research group, which was compiled with reference to the existing questionnaires at home and abroad and based on the characteristics of mathematics and the actual situation.

The first part of the questionnaire is 'basic information of students', which contains the basic information of the respondents such as 'name', 'gender', 'grade', 'class' and so on. The second part is the mathematics learning input, which is divided into three dimensions: behavior, cognition, and emotion, with three composite factors and nine specific questions under each dimension. There are a total of 27 specific questions, as shown in Table 2.

Table 2 Question setting for learning inputs

dimension	composite factor	query
behavior	level of drilling and research	Exercises to test whether new knowledge has been acquired
		Clarify the conditions for the use of various mathematical methods or theorems
		Review the key points of the lesson in time after the lesson and do exercises to consolidate them
	attention span	Pay attention in class, never pay attention to what other students are doing
		Ability to keep up with math teacher in class
	time investment	Participate in extracurricular activities in mathematics organized by the school
		Regularly do math practice materials outside of school
		Time spent on math after school each day
		Ask your parents to find a tutor to help with math
cognition	superficial cognitive strategy	When studying functions and equations, it is not considered necessary to focus on proofs
		Likes to memorize problem solving techniques and finds them effective
		For formulas and rules, it is considered that memorization is the best approach
	deep-root cognitive strategy	Math concepts not understood will be understood with examples
		Algebra, trigonometry, analytic geometry, etc. have commonalities in their methods of thinking
		Summarize problem solving techniques and patterns to avoid repetitive practice
	independent counter mental capacity	Self-organization of math studies according to individual circumstances
		Sequence multiple tasks assigned by the teacher
		Setting learning objectives according to different learning contents
emotion	the joy of learning	Can feel the wonderful conclusions in algebraic operations
		Enjoyed hearing the teacher's presentation on the important use of math
		Enjoys listening to or reading about math curiosities
	achievement orientation	Considers math to be the basis for learning physics, chemistry, computers, etc.
		Seize opportunities to learn math beyond the textbook
		Likes challenging content because you can learn new things
	anxiety	Wanting to immediately throw away or tear up papers when you don't do well in math
		Shivering and sweating during exams, always thinking about the answer time
		Fearful withdrawal when faced with geometric proofs or derivation of formulas, etc.

The degree of compliance was categorized into five categories: 'not at all compliant', 'not compliant', 'average', 'compliant', 'fully compliant', and the time spent on after-school math learning time was categorized into 'less than 0.5 hours', '0.5-1 hours', '1-2 hours', '2-3 hours', and 'more than 3 hours', which were quantified on a 5-point Likert scale from 1 to 5. In addition, the paper collected the scores of the surveyed students on their final math exams near the time of the survey as a portrayal of their academic achievement in math.

2.3 Data preprocessing

In the first part of the questionnaire, 'gender' is denoted by x_1 and assigned the value of 0 if the one is male and 1 otherwise, 'grade' is denoted by x_2 and assigned the value of 1 if the one is Senior one, 2 if the one is Senior two and 3 otherwise, and 'class' is denoted by x_3 and assigned the value of 0 if the one is in ordinary class and 1 otherwise. In the second part of the questionnaire, x_{ij} is used to indicate the specific question for the j (j=1,2,...,9) variable under the i (i=1,2,3) dimension.

For academic achievement in mathematics, test scores (on a 150-point scale) were converted to a grading scale of Fail, Pass, Medium, Good and Excellent, expressed as 1,2,3,4,5, respectively.

2.4 Continuous ratio models

This paper is devoted to exploring the factors influencing the improvement of academic achievement level, so it adopts a forward approach to construct a continuous ratio model, which can accurately and conveniently explain the relationship between the ordinal response variable and the predictor variables.

Suppose x_i is the p-dimensional covariate vector for the i-th (i=1,2,...,n) sample, y_i is an ordinal response variable. In this paper, y_i is academic achievement, which belongs to a category k, k=1,...,5. Let $\delta_k(x) = P(Y = k \mid Y \geq k, X = x)$ denote the probability that a student belongs to the category k if he or she is known to be at least in the academic achievement category k. And $1-\delta_k(x) = P(Y > k \mid Y \geq k, X = x)$ denotes the probability that a student exceeds the category k given that he or she is known to have reached at least one of the academic achievement categories k, which, at the same time, is also of interest for indicating the extent to which a student is able to exceed his or her current level of academic achievement.

In this paper, we develop a continuous ratio logistic regression model:

$$\operatorname{logit}(\delta_k(x)) = \log\left(\frac{P(Y=k \mid Y \geq k, X=x}{P(Y>k \mid Y \geq k, X=x}\right) = \alpha_k + x_i^T \beta_k, \quad k=1,2,3,4 \tag{1}$$

where $\delta_k(x)$ is the same as described earlier, α_k is the constant term of the regression model, and $\beta_k = (\beta_{k1}, \beta_{k2}, \text{L}\ , \beta_{kp})^T$ is the p-dimensional vector of regression coefficients.

Here β_{11}=L $=\beta_{4,1}=\beta_1^*$,L , β_{1p}=L $=\beta_{4,p}=\beta_p^*$ is assumed, i.e., the equal slope assumption, a constraint that simplifies the model structure and prevents over-parameterization (Archer 2012).

2.5 Implementation process

This paper proposes to study the effect of academic engagement on academic achievement in mathematics among high school students, where academic achievement level is an ordinal response variable, and therefore the data is modeled using a continuous ratio model. The original dataset is reconstructed and the reconstructed dataset can be estimated by a general logistic regression model (Alan 2002). The reconstructed dataset in this paper contains a total of 434 observations.

Since the learning input items in the questionnaire are artificially set and contain multiple factors, it is not possible to determine whether these factors truly affect academic achievement in mathematics. Therefore, it is necessary to select the factors that really affect the improvement of academic achievement in mathematics. In this paper, by constructing the forward continuous ratio model with SCAD penalty (SCAD-CR), the coefficients of unimportant variables are estimated to be zero, so as to achieve the purpose of selecting variables.

Introducing the SCAD penalty into the log-likelihood function of the continuous ratio model, i.e:

$$l(\beta \mid y, x) - n\sum_{m=1}^{p} p_\lambda(|\beta_m|) \tag{2}$$

In Eq. (2), $l(\beta \mid y, x)$ is the log-likelihood function of the model (Cox 1988), $p_\lambda(|\beta_m|)$ is the SCAD function (Fan and Li 2001), where the tuning parameter λ is selected using ten-fold cross-validation method. Important

variables can be selected and estimated by maximizing equation (2).

3. Results and Discussion

As shown in Table 3, the coefficients of the variables of gender, grade, and class in SCAD-CR are all zero, indicating that these three factors are not sufficient to influence the academic achievement of high school students in mathematics. 12 variables in the three dimensions are selected and 7 of them are significant.

Table 3 Estimates of coefficients

Dimensional	variate	SCAD-CR
gender	x_1	0.000
grade	x_2	0.000
class	x_3	0.000
behavior	x_{11}	0.000
	x_{12}	0.000
	x_{13}	0.000
	x_{14}	0.000
	x_{15}	-0.839****(0.242)
	x_{16}	0.000
	x_{17}	-0.416*(0.237)
	x_{18}	-0.428 (0.261)
	x_{19}	0.000
cognition	x_{21}	-0.050 (0.223)
	x_{22}	-0.664*** (0.218)
	x_{23}	0.000
	x_{24}	-0.225 (0.197)
	x_{25}	-0.213 (0.237)
	x_{26}	-0.321*(0.195)
	x_{27}	0.000
	x_{28}	0.000
	x_{29}	-0.358 (0.273)
emotion	x_{31}	0.000
	x_{32}	0.000
	x_{33}	0.000
	x_{34}	0.000
	x_{35}	-0.569**(0.231)
	x_{36}	0.000
	x_{37}	0.404*(0.233)
	x_{38}	0.000
	x_{39}	0.526**(0.214)

Note: **** ,*** ,** , and* indicate that the estimates are significant at the 0.1%, 1%, 5%, and 10% significance levels, respectively; standard errors of the estimates are in parentheses; coefficients of 0 indicate variables not be selected.

Specifically, x_{15} (being able to follow the math teacher in class) and x_{17} (frequently doing math practice outside of school) in the behavioral input dimension are selected, thus, it is clear that concentration on learning in class

and the time investment in practicing are necessary. x_{22} (like to memorize problem solving methods and techniques, and think they are very effective) and x_{26} (summarize problem solving techniques and rules, and avoid repetitive practice) in the dimension of cognitive input are selected and significant, which shows that the methods and strategies of learning mathematics are very important. x_{35} (seizing opportunities to learn mathematics beyond the textbook) , x_{37} (wanting to throw away or tear up test papers immediately when the math results are not satisfactory) and x_{39} (feeling fearful and retreating when encountering geometric proofs or formula derivation) in the dimension of emotion input are selected and significant, which indicate that the achievement orientation of mathematics learning has an impact on the academic achievement of senior high school students in mathematics, higher achievement orientation can give students a sense of accomplishment and pride and promote better academic achievement, and moderate anxiety in learning can be a motivation to stimulate the potential of math learning, but too much anxiety can hamper cognitive ability, and negatively affect learning.

The improvement of students' academic achievement in mathematics is the result of a combination of factors, which requires both individual efforts and the efforts of schools, families, and teachers. Based on the findings of this paper, the following recommendations are made:

First, improve concentration in classroom. The degree of concentration on listening in class directly affects the learning efficiency of students. Especially for the subject of mathematics, full attention in class is crucial. Students should stay focused in class and eliminate their own and external distractions. Such as previewing new content in advance, listening with questions, and actively participating in exchanges and interactions, can effectively improve classroom concentration. Teachers must carefully design teaching links, innovative teaching methods, make full use of digital multimedia technology, mobilize students' motivation in mathematics learning, and improve students' attention to listening.

Secondly, perform effective exercise training. The study of mathematics is inseparable from practice, through practice can deepen the understanding of mathematical knowledge. "Practice makes perfect", regular practice outside the classroom has a certain positive effect on learning of mathematics But one should also focus on summarizing the learning methods and problem-solving skills, and reduce the simple and repetitive low-level exercises. Teachers should regulate the amount of homework, carefully select and design exercises, grasp the direction and degree of mathematical training and guide students to develop good mathematical learning habits.

Third, relieve learning anxiety. High school students are faced with multiple pressures, it is inevitable to produce anxiety in the learning process, and excessive anxiety will have a negative impact on learning. Students should learn to self-regulate, adjust their math expectations, and also engage in appropriate cultural and sports activities to reduce anxiety. Teachers and parents should pay close attention to students' learning status, emphasize students' mental health, and help them relieve learning pressure and anxiety.

4. Conclusion

This paper proposes a variable selection method for the forward continuous ratio model based on SCAD penalty with academic achievement as the ordinal response variable, and explores the key influencing factors of academic achievement to promote the academic achievement effectively and realize the overall improvement of the quality of education in senior high school. Seven core variables that significantly affect the improvement of senior high school students' academic achievement in mathematics were finally selected, among which, the degree of concentration in the classroom, the high frequency of extracurricular practice, mathematical learning methods and strategies, and problem solving skills have a positive effect on the improvement of the academic achievement, and the anxiety of mathematical learning has a negative effect. The gender of the students, their grades, and the class level do not have a significant effect on improving students' academic achievement in mathematics. Thus, the key to improving academic achievement in high school mathematics lies in the students' learning status in the classroom and outside the classroom.

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