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Research on Status and Characteristics of the Mastery of Students' Mathematical Learning Strategies in Chinese Junior High Schools

Haoyang Cheng [a], Guomin Wu [b], Lan Gao [c], Jiangrong Zhu [d], Dianzhi Liu [e] *

[a, c, d, e] *Soochow University, Industrial Park, Suzhou, 215123, China*
[b] *Dongjiang Junior High School, Binhu District, Wuxi, 214013, China*

Abstract

The Diagnostic Questionnaire of Junior High School Students' Mathematical Learning Strategies was developed with high reliability and validity. This questionnaire was utilized to survey 872 students. It was found that: (a) the mastery of students' mathematical learning strategies was not ideal, (b) low performing school students grasped mathematical learning strategies poorly especially in grade 7 and the inadequate mastery of metacognitive strategies led to low mathematical achievements in low performing schools, (c) girls owned better metacognitive strategies and help-seeking strategies than boys, (d) metacognitive strategies and specific cognitive strategies were good predictors of mathematical performance.

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Keywords: Junior high school students, mathematics, mathematical learning strategies, status, characteristics;

1. Introduction

The good mastery of learning strategies makes learning process more interesting and efficient. Based on the results of western research, it was in the 1990's that researchers began to work on learning strategies in China (Liu & Guo, 1993; Liu, 1997; Zhang & Zhang, 2006). Most of their studies focused on common learning strategies including programs, rules, methods and skills of learning, which were independent of specific subjects and could be applied to any learning activity. According to existing questionnaires which were constructed with high reliability and validity (Weinstein, 1987; Pintrich & De Groot, 1990), the measure tools adapting to actual conditions of China were made (Qin, 1994; Zhou & Zhang, 2002; Zhou, Zhang, Han, & Zhang, 2005). However, it was proved that learning strategies connected to specific subjects played more important roles in improving learning performance (Shi, 2001; Liu & Sun, 2004). As a result, studies on learning strategies of different subjects, such as English and Mathematics were conducted (Yao, 2000; Chen & Geng, 2003; Liu & Huang, 2008). Mathematics is one of the most essential core subjects in elementary education. However, the studies of mathematical learning strategies only occupied 2.4% of all learning strategy studies between 1997 to 2006 in China and theoretical studies were utilized much more than empirical ones (Wu & Ge, 2007), which did not support the significance of mathematics. Among empirical studies in high schools: (a) Zhang and Lian (2007) tested eighth-grade students using math examination papers and found that the strategies applied to geometry word problems of students with distinct learning abilities

* Corresponding Author: Dianzhi Liu. Tel.: +8613812662193
E-mail address: dianzhiliu@foxmail.com

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were different, which resulted in diverse efficiencies in problem solving, (b) Tang and Qiao (2000) trained the metacognitive abilities of high school students, leading to more active learning and flexible thinking, and finally raised the students' mathematical achievements, (c) Ye (2011) invested the self-regulated learning strategies of twelfth-grade students and pointed out these strategies would contribute to better mathematical performance if they were trained well by introspecting programs.

Though some developments in research on mathematical learning strategies have been achieved in recent years in China, there have been drawbacks in one form or another: (a) some studies just examined one dimension of learning strategies or aimed at exploring strategies for particular problem types, which did not include all aspects of mathematical learning strategies, (b) the questionnaires used for research lacked comprehensive reliability and validity, which might create some deviations of the results, (c) most of these studies were conducted some years ago, which would weaken the timeliness. With the new curriculum reformation, listing the mastery of learning methods as one of the curriculum objectives, and the fast development of learning theories in China, it is necessary to construct a new questionnaire for an overall investment to accurately present the current status of the mastery of students' mathematical learning strategies in Chinese junior high schools, which will provide momentous guidance for the improvement of teaching and learning.

2. Method

2.1. Subjects

The sample included 872 students from 6 junior high schools in Suzhou and Wuxi. There were 433 boys and 421 girls. Eighteen students' information of gender was missing. There were 291 seventh-grade students, 309 eighth-grade students, and 272 ninth-grade students included in the study.

2.2. Measures

The Diagnostic Questionnaire of Junior High School Students' Mathematical Learning Strategies included four sub-questionnaires, each for one of the four dimensions: metacognitive strategies, basic cognitive strategies, specific cognitive strategies, and help-seeking strategies. The questionnaire was developed on the basis of the work of Mo and Liu (2005). Furthermore, open interview techniques were used to collect strategies that were beneficial to math learning in junior high school in order to make the elementary questionnaire. The students were instructed to respond to the items on a 5-point Likert scale (1 = *never do that* to 5 = *always do that*) in terms of the frequency of strategies used in learning mathematics. Higher scores represented better mastery of mathematical learning strategies. Accordingly, the students also did a 5-point self-evaluated test on achievement level in mathematics (1 = *very poor* to 5 = *very good*). The data of a 648-student sample was employed for exploratory factor analysis to form the final questionnaire.

Analysis showed good internal consistency and time-crossed stability of the final questionnaire (35 items, α = .94, retest reliability was .89): Metacognitive strategies (13 items, α = .89, retest reliability was .80) included two distinct factors: planning & introspecting strategies and regulating strategies. Basic cognitive strategies (7 items, α = .76, retest reliability was .81) included two distinct factors: reviewing strategies and relating & utilizing strategies. Specific cognitive strategies (9 items, α = .83, retest reliability was .84) included two distinct factors: analyzing & inferring strategies and comprehending & concluding strategies. Help-seeking strategies (6 items, α = .63, retest reliability was .82) included two distinct factors: self-help strategies and other-help strategies.

Confirmatory factor analysis revealed that: GFI, NFI, IFI, and CFI of all sub-questionnaires were higher than .90, χ^2/df of all sub-questionnaires were lower than 5.00, and RMSEA of all sub-questionnaires were lower than .08, suggesting the model was a good fit. The final questionnaire was sent to 43 experts and math teachers for assessment. The agreements of all items ranged from 72% to 98%, indicating a high expert validity. The correlation between the total score of the questionnaire and the math achievement level was .50 (p<.01), clarifying a good criterion validity.

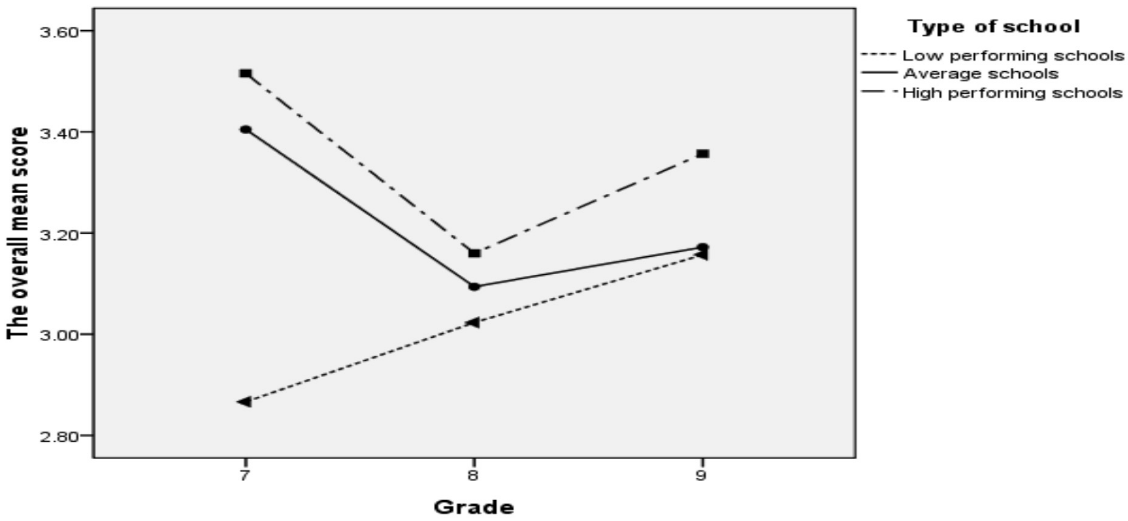

Figure 1. Interactions between type of school and grade

3. Results

3.1. The status of the mastery of junior high school students' mathematical learning strategies in China

Table 1 displayed the present situation of the mastery of students' mathematical learning strategies in Chinese junior high schools. The overall mean score was 3.21. Dimension was used as an independent variable and the mean scores of the four sub-questionnaires were dependent variables for repeated measures analysis of variance (ANOVA). There were significant differences among the mean scores of the four dimensions with the highest mean score of metacognitive strategies (M=3.35) and the lowest mean score of basic cognitive strategies (M = 3.01), F(3, 869) = 175.50, p<.001. In the view of the mean scores of all factors, regulating strategies (M = 3.88) was the highest, while self-help strategies (M = 2.94) was the lowest.

Table 1. Description of dimensions and factors

	Metacognitive			**Basic cognitive**			**Specific cognitive**			**Help-seeking**			**Overall**
	planning & introspecting	regulating	total	reviewing	relating & utilizing	total	analyzing & inferring	comprehending & concluding	total	self-help	other-help	total	
M	3.11	3.88	3.35	3.00	3.01	3.01	3.45	2.95	3.23	2.94	3.23	3.09	3.21
SD	0.77	0.77	0.71	0.79	0.89	0.73	0.78	0.84	0.74	0.80	0.85	0.68	0.64

Note. N = 872.

3.2. Influences of type of school, grade and gender

3.2.1. The influences on overall mathematical learning strategies

According to the achievements of senior high school entrance examination, schools were divided into three types: high performing schools, average schools and low performing schools. Eighteen students' data was not used for analysis because of the missing information of gender, and 854 students' data was utilized in the analysis. ANOVA was used, while type of school, grade, and gender were utilized as independent variables. The overall mean score of mathematical learning strategies was used as a dependent variable. There were two significant main effects of type of school and grade, and significant interactions between type of school and grade (Figure 1).

The univariate test for type of school was significant, $F(2, 836) = 10.73$, $p<.001$. The scores of high performing ($M = 3.40$), average ($M = 3.21$) and low performing ($M = 3.01$) schools declined in order. The univariate test for grade was significant, $F(2, 836) = 3.33$, $p<.05$. The scores of grade 7 ($M = 3.33$), grade 9 ($M = 3.20$) and grade 8 ($M = 3.09$) declined in order. The univariate test for interactions between type of school and grade was significant, $F(4, 836) = 4.49$, $p<.01$. On the basis of the results of simple effect analysis (LSD), it was found that: In grade 7, students of low performing schools had a significantly lower mean score of mathematical learning strategies ($M = 2.87$) than those of high performing ($M = 3.52$) and average ($M = 3.40$) schools, while there were no differences between students of high performing and average schools, $F(2, 288) = 20.04$, $p<.001$. However, in grade 8 and grade 9, there were no differences among students from the three types of schools.

3.2.2. The influences on each dimension

Eighteen students' data were omitted because of the missing information of gender, and 854 students' data was utilized. Type of school, grade and gender were used as independent variables and the mean scores of the four sub-questionnaires were used as dependent variables in multivariate analysis of covariance (MANCOVA). There were two significant main effects of type of school and grade, and significant interactions between type of school and grade. Meanwhile, there was a main effect of gender that was marginally significant ($p<.07$).

The multivariate test for type of school was significant, Hotelling's statistic = .07, $F(8, 1664) = 7.70$, $p<.001$. Students of high performing schools had advantages on all four dimensions, while low performing school students' mean scores were always the lowest. The multivariate test also proved significant results on grade, Hotelling's statistic = .02, $F(8, 1664) = 2.47$, $p<.05$. Students in grade 7 owned the best mean scores of all four dimensions, while eighth-grade students always had the lowest mean scores. The multivariate test for interactions between type of school and grade was significant, Hotelling's statistic = .04, $F(16, 3326) = 1.93$, $p<.05$. The multivariate test for gender was marginally significant, Hotelling's statistic = .01, $F(4, 833) = 2.19$, $p<.07$; The univariate tests for gender were significant on metacognitive strategies, $F(1, 836) = 4.39$, $p<.05$ and help-seeking strategies, $F(1, 836) = 5.07$, $p<.05$. Girls had a higher mean score ($M = 3.44$) than boys ($M = 3.27$) on metacognitive strategies. Girls' help-seeking strategies ($M = 3.17$) were also superior to boys ($M = 3.00$).

Furthermore, to analyze interactions between type of school and grade, it was found that: in grade 7, students of low performing schools had lower mean scores of all four dimensions than those of high performing and average schools, while there were no differences between students of high performing and average schools, just like the situation of overall mathematical learning strategies. On metacognitive strategies, in grade 9, students of high performing schools had higher scores ($M = 3.56$) than those of low performing ($M = 3.23$) and average ($M = 3.28$) schools, while there were no differences between students of low performing and average schools, $F(2, 269) = 3.68$, $p<.05$, and there were no differences among ninth-grade students from the three types of schools, regardless of basic cognitive strategies, specific cognitive strategies, or help-seeking strategies. Meanwhile, in grade 8, there were no differences among students from different types of schools on all four dimensions.

3.3. The logistic regression of the four dimensions' prediction for mathematical performance

Three types of students were divided according to achievement level in mathematics (1, 2 for low performing students, 3 for average students and 4, 5 for high performing students). 872 students' data was used in a logistic regression analysis, while using the mean scores of the four sub-questionnaires as independent variables and type of student as a dependent variable. The model fitted well (1639 for -2 Log Likelihood, $p<.001$; .25 for Cox and Snell, .28 for Nagelkerke and .13 for McFadden). Table 2 showed the results.

Metacognitive strategies were good predictors to discriminate between high performing and low performing students ($p<.001$), and to distinguish high performing and average students ($p<.01$). Higher scores on metacognitive strategies were strongly associated with high performing students. The OR was .25 for low performing students and .51 for average students, compared with high performing students, suggesting that the development of metacognitive strategies was more likely to foster students with good mathematical performance. Basic cognitive strategies could make a distinction between high performing and average students (p<.05), but were not effective in discriminating between high performing and low performing students. The OR was 1.59 for average students compared with high performing students, which meant emphasis on mastering basic cognitive strategies had a positive affect on average students, but not high performing students. Specific cognitive strategies were able to differentiate between high performing and low performing students (p<.001), and to divide high performing and average students (p<.01). High performing students were more likely to own higher scores on specific cognitive strategies (The OR was .26 for low performing students and .52 for average students, compared with high performing students), indicating that specific cognitive strategies were vital for good mathematical performance. However, help-seeking strategies were not good predictors, so the unilateral improvement of this dimension might not be helpful to achieve good mathematical performance.

Table 2. Results of logistic regression

Variable	Low performing students / High performing students				Average students/ High performing students			
	B	*SE*	*OR*	*95%C.I.P*	*B*	*SE*	*OR*	*95%C.I.P*
Metacognitive strategies	-1.39***	0.27	0.25	0.15-0.42	-0.68**	0.24	0.51	0.32-0.81
Basic cognitive strategies	0.29	0.23	1.33	0.85-2.10	0.46*	0.21	1.59	1.06-2.38
Specific cognitive strategies	-1.37***	0.24	0.26	0.16-0.41	-0.66**	0.22	0.52	0.34-0.79
Help-seeking strategies	0.19	0.20	1.21	0.81-1.81	-0.16	0.18	0.85	0.60-1.22

Note. N = 872. *** p<.001, ** p<.01, * p<.05. High performing students were the reference point.

4. Discussion

4.1. Analysis of the mastery of mathematical learning strategies

4.1.1. The overall analysis

The overall mean score of mathematical learning strategies was 3.21, between *sometimes do that* and *often do that*, suggesting Chinese junior high school students were unable to utilize learning strategies frequently. The status of the mastery of students' mathematical learning strategies was not ideal in Chinese junior high schools, due to the fact that Chinese teachers were used to pass on knowledge but lacked consciousness to teach learning strategies and guide students to grasp these strategies.

From the aspect of the grade variable, in high performing and average schools, the level of learning strategies first declined and then increased, as seventh-grade students owned the highest mean score, students in grade 8 had the lowest, and grade 9 students were intermediate. Previous research had revealed that entering junior high schools from primary schools was the fastest developmental stage of learning strategies (He & Liu, 1996). This result became the explanation why students in grade 7 showed the highest mean score, hinting that both students and teachers should make full use of this golden period to foster learning strategies. Another study found that the higher the grade, the more constrained use of learning strategies became in high school, because of the increasing study pressure and decreasing free time (Zhang & Zhang, 2006). This limit also might be caused by the increasing shallow-level motivation of pursuing examination scores. Nevertheless, the overall mean score of students in low performing schools kept increasing, along with the advancement in grade level, and ninth-grade students' mean score was significantly higher than seventh-grade students'. Moreover, the different levels of mathematical learning strategies among different types of schools mainly performed in grade 7. Seventh-grade students in low performing schools owned significantly lower scores, while in grades 8 and 9, there were no differences among students from different types of schools. This phenomenon indicated that in the beginning stage of junior high school, there were significant differences among different types of schools on mathematical learning strategies. Students of low performing schools occupied a comparatively low start, but possessed enormous potential. Seventh-grade students in low performing schools had not mastered mathematical learning strategies well in primary school. Meanwhile, their inability to adapt quickly enough to the learning content and environment in junior high school made the status of the mastery of mathematical learning strategies extremely poor. In spite of the unproductive beginning, students in low performing schools could keep pace with others by accumulating strategies through 3 years learning and training, because of the easy-learning essence of learning strategies and the low pressure of senior high school entrance examination in low performing schools.

Consequently, it was the most emergent thing for low performing schools to enhance the teaching and training of mathematical learning strategies in grade 7 to narrow the gap between them and other schools. For high performing and average schools, preventing the drop of learning strategies in grade 8 was the first consideration. Meanwhile, teachers should arouse students' consciousness to explore, master and apply mathematical learning strategies, and cultivate their internal motivations.

4.1.2. The analysis of metacognitive strategies

It was obvious from the results of analysis that Chinese students were skillful at controlling their learning process (M = 3.88 for regulating strategies), but weak in active planning and reflecting (M = 3.11 for planning & introspecting strategies) which were beneficial to learning mathematics. Pintrich (1990) pointed out that learning achievement would be promoted if students have enough motivational skills to utilize metacognitive strategies. The unsatisfied mastery of metacognitive strategies was the main reason for low achievements of students in low performing schools. Simultaneously, ninth-grade students in high performing schools owned better metacognitive strategies than those of average and low performing schools, while their overall mean scores were almost the same, indicating that metacognitive strategies might be critical factors for high achievements in senior high school entrance examination when the levels of overall mathematical learning strategies did not differ.

Moreover, girls' mean score of metacognitive strategies was significantly higher than boys', which was coincident with the conclusion that girls had advantages on metacognitive strategies from grade 7 to grade 12 (Wang, Yin, & Lv, 2007). Social expectations for girls, such as cautiousness, carefulness, and manners, made girls grasp metacognitive strategies better so that they were more capable of planning, introspecting, and regulating their learning behaviors. Boys seemingly needed to further heighten the mastery of metacognitive strategies.

4.1.3. The analysis of basic cognitive strategies

Basic cognitive strategies referred to the applications of learning strategies that were generally effective for different subjects in learning mathematics (e.g., *I often summarize what I have learned after math classes*, and *I contact knowledge of math with life phenomena for comprehension*). Chinese students did not pay much attention to review (M = 3.00 for reviewing strategies), due to the heavy study load that occupied the time which should have been more wisely utilized as review time. Meanwhile, the examination-oriented study made students lack the flexibility to migrate common strategies into learning mathematics (M = 3.01 for relating & utilizing strategies). These two factors influenced the mastery of students' basic cognitive strategies in Chinese junior high schools. The findings prompted teachers to recognize the importance of reviewing, to encourage them to reserve time for, and suggested that the migration of common strategies still needed to be strengthened in learning mathematics.

4.1.4. The analysis of specific cognitive strategies

Specific cognitive strategies contained particular strategies aiming at directly solving specific mathematical problems (e.g., *I will consider moving or transforming the figures, while dealing with complex geometry problems*). Unlike the situation in western countries that huge differences existed between high performing and low performing students on methods for solving problems, Chinese students closely achieved the same steps, while solving a problem (Niu & Zhang, 1998), which explained the relatively high mean score of analyzing & inferring strategies (M = 3.45). Unfortunately, the advantage of analyzing & inferring strategies brought by rigid training reduced the flexibility of thinking, which contributed to the poor mastery of comprehending & concluding strategies (M = 2.95) so that students could barely extract and summarize the main points of numerous concepts, formulae, principles, and methods in math learning. Divergent learning styles, such as brainstorming, were perfect solutions for this shortcoming of Chinese junior high school students.

4.1.5. The analysis of help-seeking strategies

Help-seeking strategies were comprised of searching learning resources by oneself and getting assistance from others. The mean score of this dimension (M = 3.09) was not satisfied. One of this dimension's factors, self-help strategies, produced the lowest mean score (M = 2.94) among all factors in the questionnaire. Even high performing students (achievement level in mathematics was 4 or 5) only had a mean score of 3.12, which reflected the dependence on assistance from others, and the absence of self-regulated learning in junior high school. Teachers must impart efficient means to their students in order for their students to achieve in mathematics satisfactorily.

Girls had a higher mean score on help-seeking strategies than boys. It was probably because of the differences in sex roles. Girls tend to be sensitive to surrounding things and it is a reasonable assumption that females would ask for assistance from others, while boys tend to be more independent, which would prevent them from seeking help from outside learning resources or others. According to this scenario, the principles of teaching and training help-seeking strategies should be geared towards gender differences. Girls should be encouraged to think independently while they seek help. Boys should be encouraged to break their negative stereotype, look for useful learning resources available, and utilize cooperative learning to master help-seeking strategies more effectively.

4.2. The analysis of the four dimensions' prediction for mathematical performance

The results of logistic regression that resulted in higher scores on metacognitive strategies were more likely to foster high performing students in learning mathematics, again reiterated the pivotal role of metacognition. At the same time, good mathematical performance partly was attributed to the skilled mastery of specific cognitive strategies containing thoughts, methods, skills, and forms that directly helped students figure out various mathematical problems. Basic cognitive strategies were only predictive when examining high performing and average students, while higher scores tended to cultivate average students, suggesting that although the advancement of this dimension might help students avoid poor mathematical performance, it was unrealistic to achieve good mathematical performance by increasing basic cognitive strategies alone.

There were two reasons why help-seeking strategies were not sufficient along, as predictors for mathematical performance. First, help-seeking strategies were neither specific means of problem solving nor summarized forms of thinking, but rather strategies aiming at helping to develop cognition so that this dimension did not promote mathematical performance directly. Secondly, as help-seeking strategies were not taught and trained sufficiently, the general low level of this dimension was responsible for the results. Nonetheless, as seeking related learning materials by oneself led to further interpretation of contents in classes (He, 2012) and active social supports profited the increasing of efficiency and confidence in study which finally contributed to the promotion of learning performance (Gao & Liu, 2011), help-seeking strategies should be a crucial aspect of strategic pedagogy at the junior high school level. Students should be taught how to seek help on the basis of self-regulated learning.

Despite the four dimensions' diverse predictive effects on mathematical performance, it was not only the dimension with a good prediction that should be emphasized. All dimensions were positive for math learning: (a) developments of metacognitive strategies and specific cognitive strategies contributed to good mathematical performance, (b) improvements on basic cognitive strategies helped to avoid remaining a low performing student and this dimension should be incorporated with specific cognitive strategies to cultivate a high performing student, (c) help-seeking strategies benefited the promotion of mathematical performance by providing immense support.

5. Conclusion

This research resulted in the following conclusions, as a result of the questionnaire survey: (a) the mastery of students' mathematical learning strategies was not ideal in Chinese junior high schools, as the mastery levels of metacognitive strategies, specific cognitive strategies, help-seeking strategies, and basic cognitive strategies declined in order. Self-help strategies of help-seeking strategies were grasped worst for all students, including high performing students. (b) Type of school affected the mastery of mathematical learning strategies, while low performing school students scored the lowest especially in grade 7. The low level of metacognitive strategies was deemed extremely accountable for low mathematical achievements in low performing schools. (c) Girls owned better metacognitive strategies and help-seeking strategies than boys. (d) Metacognitive strategies and specific cognitive strategies were good predictors of mathematical performance and the skilled masteries of them were necessary conditions for good mathematical performance.

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