Research on the Relationship between Mathematical Culture and Junior Middle School Students' Interest in Mathematics Based on PLS-SEM Analysis

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Abstract. This paper aims to analyze the relationship between mathematical culture and the interest of junior middle school students in learning mathematics. The aspects of interest examined include emotional experience, knowledge acquisition, autonomous involvement, and value recognition. The elements of mathematical culture considered are mathematical knowledge, mathematical thoughts and methods, mathematical thinking, and mathematical awareness and activities. Based on the PLS-SEM method, this study explores the path relationship from facets of mathematical culture to facets of mathematical learning interest. The results reveal that the path coefficient between the facets of mathematical culture and mathematical learning interest is positive, with acceptable effects. The evaluation results are ideal and show significance at the 0.05 level, indicating a positive correlation between mathematical culture and the interest of junior middle school students in learning mathematics. This offers valuable references for further research on mathematical culture and students' interests.

Keywords: Mathematical culture; Mathematical learning interest; Junior middle school students; PLS-SEM.

1 Introduction

Mathematical learning interest is one of the primary aspects of student learning and teacher evaluation. In the 1990s, Hidi divided interest into situational interest and individual interest based on the theory of human-environment interaction[1]. Further, she proposed four stages of interest development: triggered situational interest, maintained situational interest, emerging individual interest, and well-developed individual interest[2]. This viewpoint has become a mainstream perspective in the international community. American ethnomathematics expert ASCHER argued that students becoming aware of mathematical culture, maintaining interest in mathematics, and being able to engage in ongoing mathematical activities is a shared concern among mathematicians (whether they realize it or not) and other minority groups[3]. JONES, in the 1950s, suggested that infusing the history of mathematics in the classroom could serve as a teaching method to improve students' attitudes towards mathematics[4]. Bishop categorized

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mathematical culture into six activities: counting, measuring, locating, designing, playing, and explaining[5], providing a reference for implementing mathematical culture means to promote students' mathematical interest. McGivney-Burelle and others designed mathematical exploration activities related to latitude and temperature[6]. Cooper et al. discussed the connection between music and geometric transformations[7]. McBride & Rollins believed that the history of mathematics helps enhance students' enthusiasm for learning mathematics[8]. Jardine argued that studying the history of mathematics enriches the mathematical learning experience[9]. Fishman used poker card games to assist students in learning the concept of factors and integer factorization[10]. Goodman introduced basketball game penalty rules into probability teaching[11]. These studies reflect the relationship between mathematical culture and mathematical learning interest from activities such as geography, history, art, games, and sports. However, there's a relative lack of unified tools to evaluate the relationship between mathematical culture and mathematical learning interest. This research aims to determine the indicators of mathematical culture and mathematical learning interest for junior middle school students and analyze their relationship based on PLS-SEM. Subsequently, it presents the results of indicator construction, the relationship between mathematical culture, and junior middle school students' mathematical learning interest, and finally concludes.

2 Research Design

2.1 Operational Definitions of Research Indicators

R. Wilder expounded on the evolution of mathematics using anthropological ideas, asserting that mathematical culture is a philosophical system encompassing the development of mathematical knowledge, mathematical thought, and mathematical methods[12]. Therefore, it's challenging to provide a comprehensive and detailed explanation of mathematical culture. Given this, the present study preliminarily identifies the widely discussed and highly representative dimensions of mathematical knowledge, mathematical thought, mathematical methods, mathematical thinking, and mathematical application awareness as the measures of mathematical culture in this research. Furthermore, based on Pei Changgen's (2018) study, the essence of Chinese students' mathematical learning interest is divided into four aspects: emotional experience, knowledge acquisition, autonomous involvement, and value recognition[13].

2.2 Establishment and Encoding of Questionnaire Items

A questionnaire titled "The Impact of Mathematical Culture on Junior High School Students' Interest in Mathematics" was developed. The preliminary version of the research questionnaire contains a total of 45 questions, with responses utilizing the Likert scale format. The first part codes for gender: Male (1), Female (2); the second part consists of the questionnaire content. For lie detection items, a reverse scoring method is applied for encoding. Moreover, for any missing data in the questionnaire, the median value is used as a method of imputation.

2.3 Participants

The study was conducted from October 9 to 14, 2022. This survey utilized a simple random sampling method and targeted junior high school students in Nanning City, Guangxi Province.

322 questionnaires were distributed, with 279 valid returns, 35 invalid returns, resulting in a validity rate of 86.65%. The obtained samples were used for item analysis and exploratory factor analysis of the questionnaire.Official questionnaire survey: Conducted in November 2022, this survey again used a simple random sampling method and targeted junior high school students in Nanning City, distributing 660 questionnaires in total. 634 valid questionnaires were received, with 26 being invalid, resulting in a questionnaire validity rate of 96.06%. The acquired samples were used for analysis of the relationship between mathematical culture and junior high school students' interest in mathematical learning.

3 Research Analysis

3.1 Item Analysis

3.1.1 Descriptive Statistics and Normal Distribution Test

In terms of descriptive statistics, there were 158 male participants, accounting for 56.63%, and 121 female participants, accounting for 43.37%. The overall distribution, fluctuation, and any abnormalities in the data for both the mathematical culture dimension and the mathematical learning interest dimension showed no anomalies. A Shapiro-Wilk test was conducted separately for individual items, the mathematical culture dimension, and the mathematical learning interest dimension. The study found that the p-values for all three levels were less than 0.05. However, the absolute values of the peaks were all less than 10, and the absolute values of the skewness were all less than 3. Therefore, the sample can be considered to approximately follow a normal distribution.

3.1.2 Discriminative Power Test

Through item analysis (discriminative power), there was no significant difference between the high and low groups for item Q12 ($p>0.05$). This implies that Q12 has poor discriminative power, and this item should be removed.

3.1.3 Correlation Analysis

After excluding the lie-detecting items and conducting a correlation analysis, items that did not satisfy ($r<=0.4$) included the mathematical culture questionnaire and Q6. Though they showed a significant relationship of 0.01, their correlation coefficient was ($0.373<0.4$). Hence, in practical measurement, item 6 should be removed. After item analysis, there remained 39 items (excluding the lie-detecting items).

3.2 Exploratory Factor Analysis

Based on the initial data obtained, the survey and its various dimensions were subjected to the KMO test and Bartlett's test of sphericity. The overall KMO values for the questionnaire and each dimension ranged between 0.861 and 0.883. The corresponding values for Bartlett's test of sphericity were significant ($p<0.01$). As a result, it was deemed appropriate to conduct exploratory factor analysis. Through the extraction of common factor variance, scree plot, and maximum variance rotation, the dimensions and items of the questionnaire were determined. Item loadings greater than 0.452 indicate a close relationship between these items and their respective factor dimensions. The cumulative contribution rate of the common factor variance for the four factors was 59.98%, and the explanation provided by each item for the questionnaire was above 0.426. This indicates that these factors can effectively capture the main information of the original variables.

In terms of the dimension of mathematical learning interest, item loadings were above 0.424, demonstrating a close relationship between these items and their corresponding factor dimensions. The cumulative contribution rate of the common factor variance for the four factors was 68.19%. The explanation provided by each item for the questionnaire was above 0.568, suggesting that these factors can adequately capture the main information of the original variables.

In summary, after item analysis, discriminant validity testing, correlation testing, and exploratory factor analysis, 13 items with insignificant relationships were removed. The dimensions of mathematical culture were identified as "mathematical knowledge, mathematical thought and methods, mathematical thinking, and mathematical awareness and activity." The dimensions of mathematical learning interest remained unchanged.

4 Analysis of the Relationship Between Mathematical Culture and Junior High School Students' Interest in Mathematics

For convenience, each dimension was encoded using the initial uppercase letters of their English translations. Specifically, "Mathematical Knowledge" was coded as "MK," "Mathematical Thought and Methods" as "MTAM," "Mathematical Thinking" as "MT," "Mathematical Awareness and Activity" as "MAAA," "Emotional Experience" as "EE," "Knowledge Acquisition" as "KA," "Independent Involvement" as "I I," and "Perception of Value" as "POV." Based on the data collected in the second round, the relationship between mathematical culture and junior high school students' interest in mathematics was generated by running the Bootstrapping algorithm in SmartPLS4. The results are detailed in Figure 1.

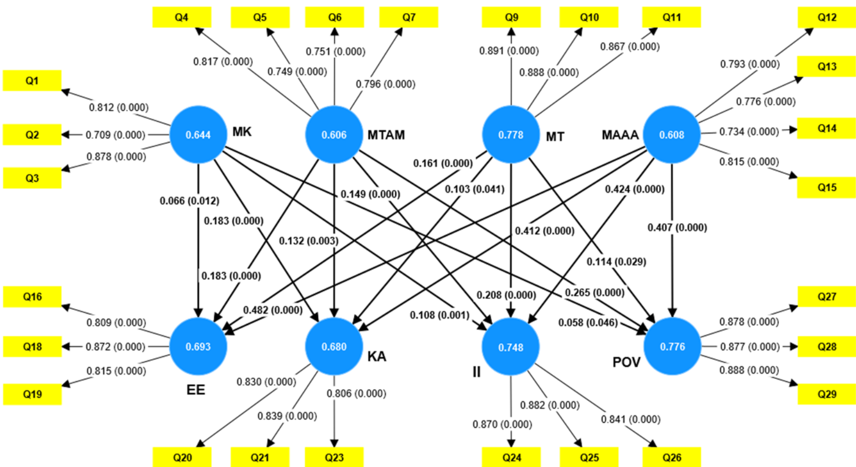

Fig.1. Relationship model between mathematical culture and junior high school students' interest in mathematics (Illustrated by the researcher).

4.1 Convergent Validity (AVE) Analysis

By observing the central values (Average Variance Extracted, AVE) of each measurement construct in Figure 1, we can determine: MK (AVE=0.644>0.5), MTAM (AVE=0.606>0.5), MT (AVE=0.778>0.5), MAAA (AVE=0.608>0.5), EE (AVE=0.693>0.5), KA (AVE=0.680>0.5), II (AVE=0.748>0.5), and POV (AVE=0.776>0.5). This suggests that there is a strong positive correlation between the respective measurement indicators, with each being able to explain more than half of the construct's variance.

4.2 Analysis of Path Relationships Between Constructs

In conjunction with Figure 1, a table illustrating the path relationships between mathematical culture and junior high school students' interest in mathematics has been constructed, as shown in Table 1.

Table 1 Path Relationship Between Mathematical Culture and Junior High School Students' Interest in Mathematics.

Relationship	Path Coefficientλ	t	p	95% CILL	95% CIUL	Relationship	Path Coefficientλ	t	p	95% CILL	95% CIUL
MK -> EE	0.066	2.501	0.012	0.017	0.120	MK -> II	0.108	3.427	0.001	0.047	0.17
MTAM -> EE	0.183	4.166	0.000	0.098	0.270	MTAM -> II	0.149	3.632	0.000	0.069	0.229
MT -> EE	0.161	3.740	0.000	0.076	0.245	MT -> II	0.208	4.421	0.000	0.114	0.299
MAAA -> EE	0.482	11.967	0.000	0.397	0.556	MAAA -> II	0.424	9.333	0.000	0.333	0.509
MK -> KA	0.183	5.823	0.000	0.122	0.246	MK -> POV	0.058	1.992	0.046	0.004	0.118
MTAM -> KA	0.132	2.940	0.003	0.049	0.224	MTAM -> POV	0.265	5.435	0.000	0.172	0.361
MT -> KA	0.103	2.048	0.041	0.007	0.206	MT -> POV	0.114	2.185	0.029	0.010	0.216
MAAA -> KA	0.412	7.864	0.000	0.305	0.509	MAAA -> POV	0.058	1.992	0.000	0.306	0.502

Based on research by Fornell & Larcker (1981) [14] and Hair, Ringle & Sarstedt (2011) [15], the evaluation of path relationships is conducted using the Bootstrapping technique in SmartPLS4 to assess significance, providing confidence intervals, path coefficients, t-values, and P-values for the path evaluation results. Observing Table 6 and Figure 1:Under the path from MK -> EE, the path coefficient ($\lambda=0.066>0$) is considered acceptable, and the path evaluation result ($t=2.501>1.96$) is ideal. The confidence interval lies between 0.017~0.120, excluding 0, and is significant at the given 0.05 level ($p=0.012<0.05$), meeting academic requirements. This suggests that MK has a significant positive impact on EE. Similarly, based on the confidence intervals, path coefficients, t-values, and P-values, it's evident that the constructs of Mathematical Knowledge (MK), Mathematical Thought and Methods (MTAM), Mathematical Thinking (MT), and Mathematical Awareness and Activity (MAAA) each have a significant positive impact on the constructs of Emotional Experience (EE), Knowledge Acquisition (KA), Independent Input (II), and Value Recognition (POV).

5. Discussion

The study found a positive correlation between mathematical culture and junior high school students' emotional experiences. The research indicates that mathematical knowledge and mathematical thought and methods have a significant positive impact on junior high school students' emotional experiences (t=2.501, p=0.012; t=4.166, p=0.000). The study also showed that mathematical thinking and mathematical awareness and activity have a significant positive effect on junior high school students' emotional experiences (t=3.740, p=0.00; t=11.967, p=0.000).

Further research revealed a positive relationship between mathematical culture and knowledge acquisition among junior high school students. Mathematical knowledge and mathematical thought and methods have a significant positive effect on junior high school students' knowledge acquisition (t=5.823, p=0.000; t=2.940, p=0.003). The development of mathematical thinking has increased the pleasure of acquiring knowledge. The study also indicated that mathematical thinking and mathematical awareness and activity have a significant positive impact on junior high school students' knowledge acquisition (t=2.048, p=0.041; T=7.864, p=0.000).

The research discovered a positive relationship between mathematical culture and the independent input of junior high school students. Mathematical knowledge and mathematical thought and methods significantly and positively influence junior high school students' independent input (t=3.427, p=0.001, t=3.632, p=0.000). Mathematical thinking and mathematical awareness and activity have a significant positive effect on junior high school students' independent input (t=4.421, p=0.000; t=9.333, p=0.000).

The study found a positive correlation between mathematical culture and the value recognition of junior high school students. Mathematical knowledge and mathematical thought and methods have a significant positive effect on junior high school students' value recognition (t=1.992, p=0.046; t=5.435, p=0.000). The research also indicated that mathematical thinking and mathematical awareness and activity have a significant positive impact on junior high school students' value recognition (t=2.185, p=0.029; t=1.992, p=0.000).

6. Conclusion

This study initially established mathematical culture assessment indicators and mathematics learning interest assessment indicators for junior high school students. The research indicates a positive correlation between mathematical culture and junior high school students' interest in mathematics, providing valuable reference for studies on mathematical culture and junior high school students' interest in mathematics.

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