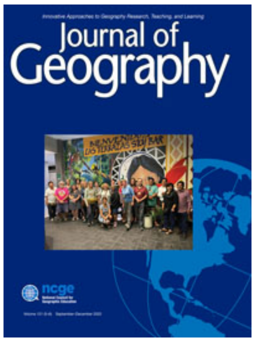

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The Mediating Effect of Academic Achievement in Geography on the Relationship between Family Capital and Geospatial Thinking

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ABSTRACT
This study examined how the family capital of upper secondary school students impacted on their geospatial thinking skills and explored the mediating effect of their academic achievement in geography. A total of 1,018 upper secondary school students participated. The results of our mediation analysis conducted using the PROCESS modeling tool revealed that family capital has a direct predictive effect on students' geospatial thinking and an indirect predictive effect via their academic achievement in geography. Therefore, this paper aims to redistribute family capital, so as to effectively apply it to the cultivation of students' geographic academic achievement and geographic spatial thinking ability.

KEYWORDS
Family capital; geospatial thinking; geography; academic achievement; income levels

Introduction

We are currently in the information age, where people often rely on geographic information technology for daily travel, which requires citizens to have relevant spatial thinking skills (Lee and Bednarz 2012). In the fields of science, technology, engineering and mathematics (STEM), spatial thinking also plays a significant role (Wai, Lubinksi, and Benbow 2009; Holly 2013). *Learning to Think Spatially* published by the National Research Council has recognized the importance of spatial thinking (National Research Council (NRC) 2006), which is conceptualized as the constructive integration of spatial concepts, representational tools, and reasoning processes. This report has stimulated the reflection and attention of geography educators in the field of spatial thinking because of its focus on spatial distribution, time evolution processes and regional characteristics of elements of geographical elements or complexes. Therefore, spatial thinking has become a feature of the discipline of geography.

Many researchers define spatial thinking to solve geographic problems as geospatial thinking (Alec 2011; Wan et al. 2017; Xie et al. 2021), which has far-reaching effects in the geographical environment. Current research on geospatial thinking among students focuses on the educational context (Metoyer and Bednarz 2016). Many studies have pointed out that the application of geographic information technology can improve the level of students' geospatial thinking, such as 3 D technology (Carrera and Asensio 2016), and GIS courses (Lee and Bednarz 2009; Minsung and Robert 2013). Another part of the research seeks training programs by exploring influencing factors. For example, Wan et al. (2017) and Xie et al. (2021) have demonstrated intelligence, geography academic achievement and interest affect upper secondary school students' geospatial thinking.

However, the family also is an important site for students' development and achievements (Mercado et al. 2016). The research on spatial thinking of lower school or preschool children pays more attention to the influence of family education. Research has shown that parents' spatial language (Pruden, Levine, and Huttenlocher 2011; Levine 2010) and gestures (Clingan Siverly Sam, et al. 2021) promote the development of children's spatial thinking in the process of interacting with their children. Furthermore, researchers found that parents of preschool children with high spatial thinking levels turned their attention to the spatial and graphic relationships in the book during the teaching process of picture books, and in jigsaw puzzles (Szechter and Liben 2004). In daily life, parents taking their children grocery shopping (Bryant et al. 2019) or traveling (Loomis et al. 1999) can help children think about space and stimulate their imagination. Verma's (2014) study also found that children from families whose parents have high income and educational scores had higher levels of spatial thinking than children with lower socioeconomic status. It can be seen that family education and family environment have a positive impact on the students' spatial thinking level (Harju-Luukkainen et al. 2020).

Therefore, it can be seen that many factors in family education will affect students' spatial thinking, but these factors are relatively complicated. After reviewing literature, this paper attempts to summarize these factors, and to explore the geographical space from the perspective of family capital influence of thinking. Because family capital is divided into three categories: family economic capital, family cultural

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capital and family social capital. Many of the above factors are the mapping of family capital, such as family social status, parenting style and so on. Therefore, this paper first deconstructs and analyzes family capital, and explores the influence of family capital on geospatial thinking and its influence path.

Since family capital is an external influencing factor of geospatial thinking, it is difficult to directly explain the mechanism through which family capital affects geospatial thinking. Therefore, geographic academic achievement, which can essentially affect geospatial thinking, is introduced as an intermediary variable to construct from family capital to academic achievement in geography, to the influence mechanism of geospatial thinking. By reviewing literature, it is found that academic achievement is closely related to family capital and geospatial thinking. First, the research on the impact of family capital on students' academic achievement is very mature. Coleman found that the school's educational equipment, teacher education level and other factors have no significant impact on students' academic performance, but the effective interaction between parents and children in the family, as well as the trust between parents and children will have a significant impact (Coleman Report, 1998). Several studies have also pointed out that family environment and socioeconomic resources of adolescents can affect their educational level (Wilder 2014). From this perspective, several studies have directly analyzed the impact of students' academic performance from the perspective of family capital. The results show that family capital is positively correlated with academic achievement and has a positive predictive effect (Parcel, Dufur, and Zito 2010; Lindfors et al. 2018; Rogošić and Silvia 2018; Xie and Ma 2019; Peng and Kievit 2020). On the other hand, academic achievement is also an important factor affecting spatial thinking. The research of Kinnari (2019) shows that geographic expertise affects the level of geospatial thinking of novices and experts alike. At the same time, the researches of Wan et al. (2017) and Xie et al. (2021) show that students' academic performance in geography affects students' geospatial thinking.

Therefore, this paper assumes academic achievement as the mediating variable between family capital and geospatial thinking ability and collects sample data extensively in 9 provinces in China, trying to verify the establishment and universality of the mediating relationship through data analysis. As a mediator variable, whether geographic academic achievement plays a partial or complete mediation mechanism in the model is not clear. The so-called complete intermediary means that family capital promotes the development of geospatial thinking through the improvement of academic achievement. The development of geospatial thinking plays a role; and part of the intermediary means that family capital can directly affect the development of geospatial thinking in addition to academic achievements. Therefore, this paper assumes these two models, including the full mediation model and the partial mediation model, and further uses the data to explore how either model can explain the relationship between family capital and geospatial thinking better. Because family capital has its own specific structural components, academic achievement may be more correlated with certain structural components and have a more direct and effective impact on geospatial thinking. By comparing which structural components of family capital have a more significant relationship between the high and low spatial thinking group samples, and which structural components of family capital has a more significant relationship between the high and low academic achievement samples, it is helpful to explore the nature of the influence of family capital on academic achievement and geospatial thinking. Starting from these factors, it can improve students' geography academic achievement and geospatial thinking ability.

Review

Spatial thinking and geospatial thinking

The development of spatial thinking was first studied in the field of psychology, where psychologists investigated issues such as spatial visualization, spatial orientation, mental rotation, and spatial perception (Pruden, Levine, and Huttenlocher 2011; Johnson 2020). As research progressed, psychologists pursued exploration in how spatial thinking interfaces with areas such as atomic structure, architecture, etc. This gives geography, chemistry and other STEM subjects (science, technology, engineering and math) important motivation to study spatial thinking (Uttal et al. 2012; Taylor and Hutton 2013). At the same time, the publication of *Learning to Think Spatially* (NRC 2006) clearly pointed out the definition of spatial thinking from an authoritative point of view, that is the constructive integration of spatial concepts, representational tools, and reasoning processes, and proposed the use of GIS to cultivate the spatial thinking level of students in various academic stages teaching advice. As a geographic information technology software, GIS has stimulated the study of spatial thinking in the discipline of geography. Due to the existence of geospatial problems on the earth's surface, problem solving usually requires attention to geospatial relationships and spatial structure transformations. For example, structural geologists need to infer the processes that lead to the formation of current geological features, and these processes are often of a spatial nature (Fu 2017). Therefore, spatiality forms an important feature of the discipline of geography, and many geographers refer to spatial thinking from the perspective of geography as geospatial thinking (Alec 2011; Wan et al. 2017; Xie et al. 2021).

In the context of geography, many scholars have classified and studied geospatial concepts, starting from basic concepts to help understand geospatial thinking, and provide a certain knowledge base for primary and secondary schools to cultivate geospatial thinking (Battersby and Golledge 2006; Golledge, Marsh, and Battersby 2008). On this basis, Kastens, Pistolesi, and Passow (2014) believes that spatial thinking in the context of earth science manipulates and acquires meaning from position and orientation, mainly the creation of objects in two dimensions and the reasoning of objects in three dimensions. Favier (2014) pointed out that geospatial thinking takes the earth's environment as the object and needs to solve geographic problems with the help of specific geographic information rather than abstract concepts. Therefore, geographers pay more attention to the related research on the spatial location and spatial relationship of the earth's surface (Verma 2015; Collins 2017). Xie et al. (2021) especially emphasized the difference between geospatial thinking and spatial thinking in research, emphasizing that geospatial thinking occurs on the earth scale and requires certain geographic knowledge, and pointed out that geospatial thinking is the human understanding of spatial information on computers or maps. It is reflected in the process of spatial analysis and reasoning focusing on spatial relationships in the geographical environment with the help of certain geospatial knowledge and tools.

In the study of geospatial thinking, the *Learning to Think Spatially* (NRC 2006) authors pointed out that spatial thinking is teachable and advocated that GIS cultivate students' spatial thinking. Therefore, most of the research focuses on the relationship between technology and geospatial thinking. For example, current research points to ArcGIS software (Lee and Bednarz 2009), Google Earth (Xiang and Liu 2017), electronic maps (Nielsen and Sugumaran 2011), action games (Price et al. 2014), VR (Hauptman and Cohen 2011) , GIT (Alec 2011) and other technologies can promote the development of students' geospatial thinking. And from these studies, the assessment and measurement of geospatial thinking is extended. Battersby, Golledge, and Marsh (2006) asked participants to analyze the spatial relationship of two maps to assess map coverage capabilities in GIS software. Lee and Bednarz (2009) conducted an in-depth study of the concepts and dimensions of geospatial thinking, developing and applying the Spatial Skills Test (SST) to measure changes in students' spatial skills after engaging in GIS studies. In 2012, Lee and Bednarz updated the test to conform to the Teacher's Guide to Modern Geography (TGMG), resulting in the Spatial Thinking Ability Test (STAT). Currently, the scale has been used in more than 20 studies in 8 countries, so the scale is of good quality and popularity (Bednarz and Lee 2019). Spatial thinking helps humans analyze, understand, and reason about spatial relationships in real and virtual environments (Kinnari Atit1 2020). Cohen and Hegarty (2012) constructed the Santa Barbara Solids Test for 3 D graphics, combined with the Mental Rotation Test (Vandenberg and Kuse 1978) and Visualization of Views Test (Eliot and Smith 1983) in psychological research, the final result is a spatial thinking test.

Family capital

The Coleman Report shows that students' academic achievement strongly relates to family factors, which has instigated citizens' attention and attention to family education (Mosteller 2010). Jane Coleman (1988) divides family capital into three groups: physical capital, human capital and social capital. Bourdieu further introduced the concept of cultural capital across the disciplines of economics and sociology. Drawing on existing literature, family capital applied in this study includes family economic capital, family cultural capital and family social capital. Family economic capital refers to household wealth, especially economic status and resources available to the household and children, this includes quantity of electrical appliances, cars and other items, etc., as well as intangible economic capital such as household income and property rights (Wilder 2014). In relation to family education, it is not only economic investment, but also emotional investment. Parents should use economic capital reasonably in their children's education, otherwise the impact on their children's education will be small. Family cultural capital refers to the cognitive ability and educational level of parents, which can provide a cognitive environment conducive to intellectual development (Xie and Ma 2019). Parents can create a cultural environment for their children, invest cultural resources and cultural attention, and help children improve their thinking ability in the potential cognitive environment. Coleman (1988) pointed out that social capital is a structure that exists in interpersonal networks. Family social capital refers to the interactions between parents and children and the social relationships of parents themselves (Rogošić and Silvia 2018; Lindfors et al. 2018). Family economic, cultural and social capital can shape children's current and future educational and career trajectories through economic resources and interpersonal cultural exchanges (Bucx, van Wel, and Knijn 2012). Family capital has its own special manifestations and extension forms. In the related research on spatial thinking, many studies have shown that family economic capital factors such as parental economic income, family socioeconomic status, family travel willingness and experience have a positive predictive effect on spatial thinking (Loomis et al. 1999; Susan et al. 2005; Antiniene and Lekaviciene 2011; Verma 2014). In cultural capital, parents' education level and parenting style (such as spatial language, gestures, and picture book teaching) will also have an impact on children's spatial thinking (Levine 2010; Pruden, Levine, and Huttenlocher 2011; Bryant et al. 2019) . In social capital, many studies have explored the relationship between occupational type, social status and spatial thinking (Wai, Lubinski, and Benbow 2009; Uttal et al. 2012; Holly 2013).

Academic achievement in geography

Academic achievement refers to student's overall performance in school and is mainly measured by academic performance, knowledge and skill acquisition (Lebcir, Wells, and Bond 2008; Jayanthi et al. 2014). Academic achievement in geography refers to the comprehensive performance of students' professional knowledge, learning interest, geography reading and related skills in geography learning (Wan et al. 2017; Xie et al. 2021). Geography academic achievement in this study mainly refers to the reflection of students' geographic knowledge and their skill level. Because geography is a discipline that studies the laws of spatial distribution and the process of time evolution, geographic knowledge and skills include spatial knowledge and spatial skills, such as knowledge of cardinal directions and the ability to judge the relative position of two things on a map. These are all part of academic achievement in geography.

Academic achievement in geography has a positive impact on geospatial thinking. Uttal (2012) found that people with a high level of spatial knowledge also had a high level of spatial task completion, while Wan et al. (2017) and Xie et al. (2021) found that through the empirical research confirms that academic achievement in geography has a positive effect on geospatial thinking.

Method

Participants

In order to select a number of schools in a sub-regional, hierarchical and balanced way across China for relevant tests and investigations, we recruited a total of ten schools based on the region where the school is located, the type of city, whether the school is in an ethnic minority area, and the level of the school. The recruitment method involved sending an application to the school to carry out the geospatial thinking ability test and survey of high school students. One of the schools chose not to participate in this survey, and the recruitment efficiency rate was 90%. The survey did not take place during class time and was arranged by the geography teacher during the self-study class. Participants were ultimately selected from nine high schools in eastern, central and western China. The eastern region includes Shanghai, Fujian, and Guangdong; the central region includes Inner Mongolia, Anhui, and Jiangxi; the western region includes Tibet, Gansu, and Yunnan. A total of 1033 students participated in the study and completed the questionnaire. After we sorted out and eliminated the invalid questionnaires, a total of 1018 questionnaires remained. The study was approved by an ethical review board, and student participation was voluntary. We anonymized student data to ensure their privacy.

Instrument and data collection

To measure students' geospatial thinking ability, this study used the Geospatial Thinking Ability Scale STAT developed by Lee and Bednarz (2012). For example, in the dimension of "overlaying and decomposing maps," participants are required to superimpose or decompose layers in their minds (Figure 1). During this process, participants are required to select the correct layer and process multi-layer images. In the test questions, developers use simple graphics to examine the ability of participants to superimpose and decompose layers. In geographic learning, they need to have the ability to overlay and decompose real geographic layers. For example, the sphere model invented by Moorman et al. (2021), which is based on the underlying model and opaque grayscale elevation data (black for sea level and white for maximum elevation; Figure 2), students need to overlay or decompose layers according to specific problems, such as various layers such as precipitation, air temperature, population, etc., and obtain information and analyze information from overlaying and decomposing images according to the problem. In this process, students need the spatial thinking ability of layer stacking and decomposing dimensions.

STAT includes 16 items for assessing and analyzing students' geospatial thinking skills. Each correct answer is assigned a point, with a maximum total of 16 points. Results from previous studies in eight countries validated the reliability and validity of the STAT scale (Bednarz and Lee 2019). Wan et al. (2017) translated the scale into Chinese to measure the geospatial thinking ability of high school students in Gansu Province and verify its applicability. After we back-translated the Chinese version of STAT into English, we found that the meaning of the expression did not change, indicating that the translation did not adversely affect the content of the scale. In our study, the reliability of the STAT scale was measured using Cronbach's alpha, which was 0.726.

We developed the Family Capital Questionnaire by adapting and modifying the Family Information Questionnaire applied in the International Student Assessment Program. In the assessment of the level of household economic capital, the household's possessions are used as the measurement standard. In the measurement of household economic capital, the basic situation of students' household computers, tablets, and mobile phones, learning environment, equipment, books, etc., is investigated. In the evaluation of family social capital, it is mainly measured according to the occupational structure of the family, and it is assigned points according to occupational points and social prestige. Among them, 1 point for retirement, unemployed; 2 points for freelancers, self-employed persons/contractors, ordinary workers (such as factory workers/manual laborers, etc.), commercial service workers (such as salespersons/store clerks/waiters, etc.); 3 points for ordinary employees (office/office building staff); 4 points for business managers; 5 points for professionals (such as doctors/lawyers/stylistics/journalists/teachers, etc.) and government/organ cadres/civil servants. The parents' education level was used to measure their family cultural capital, on a scale from 1 to 7 based on their education level. 1 point for primary school and below, 2 points for junior high school education, 3 points for high school/secondary school/technical school education, 4 points for the college degree, 5 points for the undergraduate degree, 6 points for master's degree, and 7 points for doctoral degree. The value of the Cronbach's alpha coefficient for the Family Capital Questionnaire was 0.735.

We extracted the geographic academic achievement questionnaire from the Student Common Part Questionnaire applied in the International Student Assessment Program. We evaluated scores using the students' responses to the following two items: (1) What is the range of your geography test scores? (2) What is your ranking in the geography test? The value of the Cronbach's alpha coefficient for the Geography Academic Achievement Questionnaire was 0.776.

Data analysis

In this study, we used SPSS 22.0 to perform descriptive statistical analysis and correlation analysis and tested the mediation effect with the PROCESS tool in this statistical package. First, descriptive analysis of the data was performed

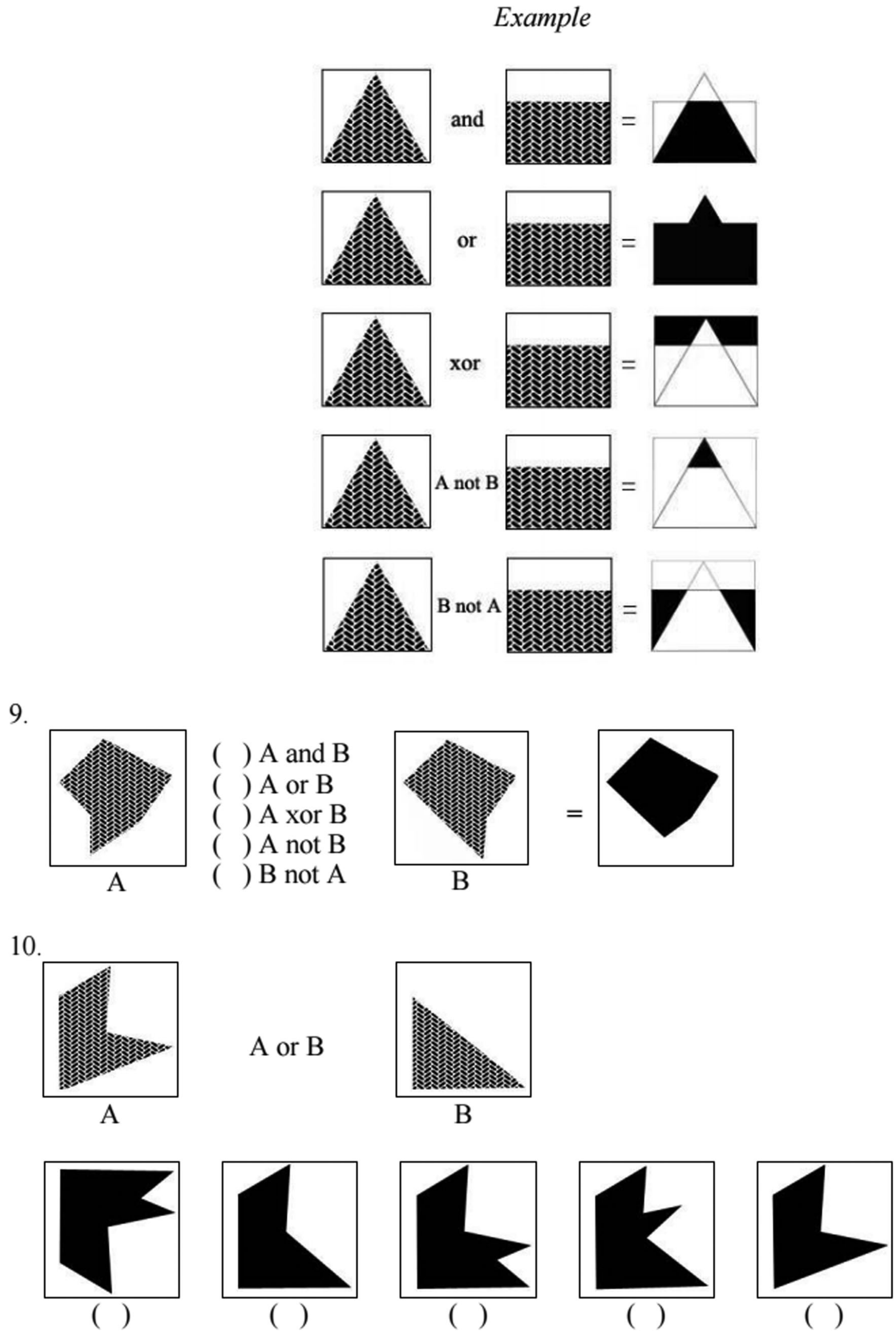

Figure 1. Questions 9 and 10 of STAT.

using SPSS software. Second, we used the calculation of Pearson to calculate the correlation between variables. Finally, using the PROCESS plugin in SPSS, which Hayes (2013) pointed out the mediating and moderating effects of using the plugin to analyze data. Among them, the conditions for verifying whether the mediation model is established should check whether the confidence interval contains 0. If the confidence interval of the mediator variable

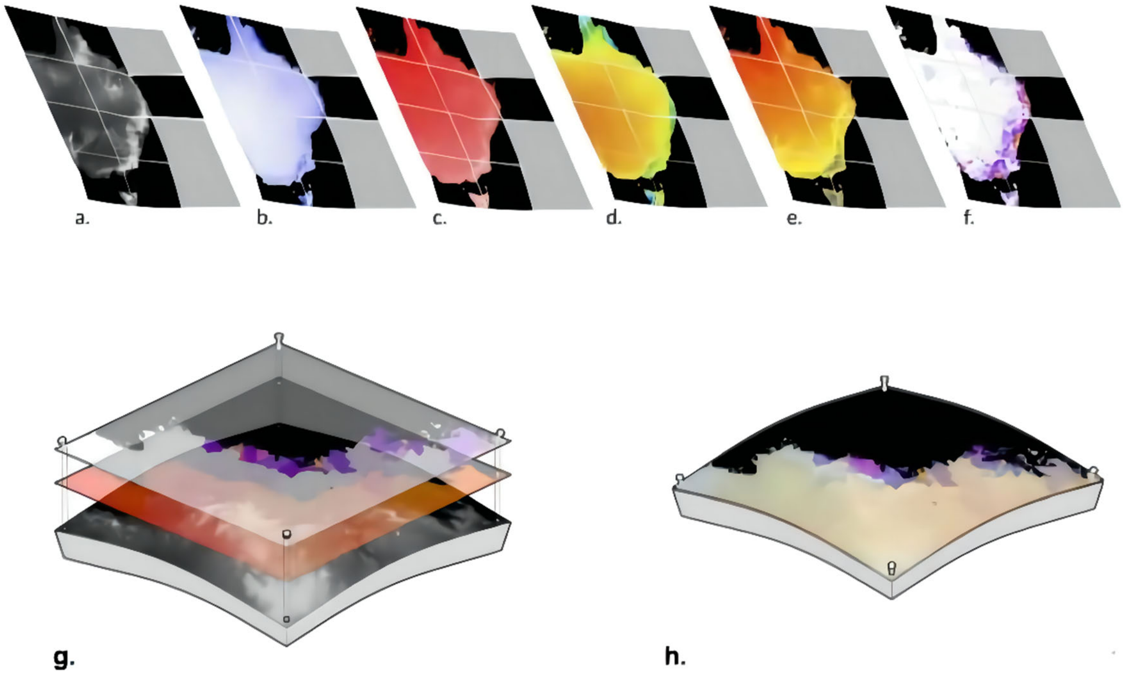

Figure 2. (a-f) Layers of different data layers; (g-h) layer overlay. From Moorman et al. (2021).

Table 1. Descriptive statistics and correlations among variables.

Variables	Mean	SD	1	2	3	4	5	6
(1) GT	73.09	18.15	1					
(2) GAA	55.81	19.02	0.288**	1				
(3) EC	56.80	13.44	0.192**	0.275**	1			
(4) CC	37.59	17.09	0.159**	0.266**	0.522**	1		
(5) SC	55.23	21.58	0.180**	0.186**	0.346**	0.59**	1	
(6) FC	149.62	42.59	0.216**	0.288**	0.7**	0.865**	0.853**	1

Note: N = 1018. GT, geospatial thinking; GAA, geography academic achievement; EC, family economic capital; CC, family culture capital; SC, family social capital; FC, family capital.**$p < .01$, *$p < .05$.

contains 0, the mediation effect is not significant. If it does not contain 0, the indication is obvious. Among them, the dimensions of each scale are unified to 100 points for data analysis.

Results

Descriptive statistics and correlation analysis

We examined the means, standard deviations, and correlations of the study variables, as shown in Table 1. The results show that geospatial thinking has a significant positive correlation with geographic academic achievement, family economic capital, family cultural capital, family social capital, and family capital. There is also a positive correlation between the variables, so the correlation analysis results meet the precondition of the mediation effect test.

Analysis of mediators of geography academic achievement

If the independent variable X affects the dependent variable Y through the variable M, M is the mediating variable between X and Y. In this paper, it is assumed that family capital (dependent variable X) can influence students' geospatial thinking (dependent variable Y) through academic achievement (mediating variable M). Generally speaking, the current method to test the establishment of the mediation effect at home and abroad is the causal stepwise regression method proposed by Baron and Kenny (1986).

This method requires three steps to test the method (Figure 3). First, the regression of family capital (dependent variable X) on geospatial thinking (dependent variable Y), that is, $Y = cX + e_1$, and the significance of the regression coefficient c is tested, which is brought into this paper. The formula for the data (see Table 2) is,

$$Y = 0.092x + 59.339 \quad (1)$$

In the second step, X is regressed to M, that is, $M = aX + e_2$, and the significance of the regression coefficient a is tested, and the formula is obtained (see Table 3) as

$$M = 0.129x + 36.548 \quad (2)$$

The third step, the regression of X and M to Y, that is, $Y = c'X + bM + e_3$, test the significance of the regression coefficients b and c', and the formula (see Table 4) is

$$Y = 0.062x + 0.235M + 50.746 \quad (3)$$

If the coefficients c, a and b are all significant, there is a mediating effect. If the coefficient c' is not significant, the mediation effect is a complete mediation effect; if the regression coefficient c is significant, the mediation effect is a partial mediation effect. Among them, the coefficients p of c, a and b are all less than 0.001, indicating that the regression is significant, indicating that there is a mediating effect, and the regression coefficient c is also significant, indicating that the mediation is a partial mediating effect.

Because the stepwise regression method is used for mediation testing in SPSS, tedious segmentation testing steps are required. Therefore, Hayes (2013) developed a plug-in

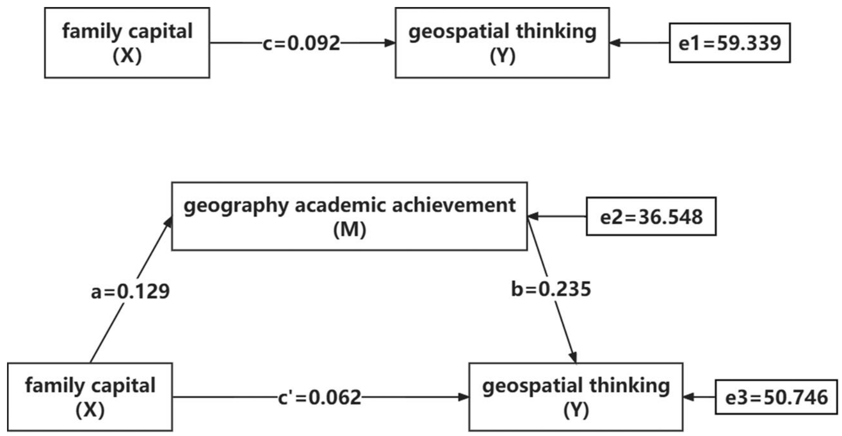

Figure 3. Mediation model with academic achievement as the mediator.

Table 2. Regression equation of family capital (dependent variable X) on geospatial thinking (dependent variable Y).

	Unstandardized coefficient		Standardized coefficient		
	B	SE	Beta	T	Significant difference
Constant	59.339	2.031		29.223	0.000
Family capital	0.092	0.013	0.216	7.041	0.000

Table 3. Regression equation of family capital (dependent variable X) on academic achievement (mediating variable M).

	Unstandardized coefficient		Standardized coefficient		
	B	SE	Beta	T	Significant difference
Constant	36.548	2.087		17.512	0.000
Family capital	0.129	0.013	0.288	9.593	0.000

Table 4. Regression equations of family capital (dependent variable X) and academic achievement (mediating variable M) on geospatial thinking (dependent variable Y).

	Unstandardized coefficient		Standardized coefficient		
	B	SE	Beta	T	Significant difference
Constant	50.746	2.249		22.561	0.000
Family capital	0.062	0.013	0.145	4.658	0.000
Academic achievement	0.235	0.030	0.246	7.934	

PROCESS that can be applied to SPSS. Comparing the two methods, the plug-in can directly analyze the mediation effect, moderation effect or mediation moderation effect. And can realize the automatic processing of data before analysis, Bootstrap and Sobel test automatic processing. Therefore, the mediation analysis of other variables in this paper was completed using the PROCESS plug-in, and the Bootstrap test was used for verification.

This paper uses the Model 4 mediation model of the PROCESS plug-in in SPSS, with family capital as the independent variable, geospatial thinking as the dependent variable, and geographic academic achievement as the mediating variable. In Table 5, family capital was positively associated with geospatial thinking ($\beta = 0.062$, SE= 0.013, $p < 0.001$) and significantly predicted geospatial thinking. Family capital positively predicted geography academic achievement ($\beta = 0.129$, SE = 0.013, $p < 0.001$) , and geography academic achievement positively predicted geospatial thinking ($\beta = 0.235$, SE = 0.03, $p < 0.001$). Draw the model structure diagram according to the path coefficients, see Figure 4.

We tested the confidence interval estimates using the bootstrap method and found that the 95% confidence intervals for the direct and indirect effects of family capital on geospatial thinking did not contain 0. Therefore, the partial mediation effect model is established, and geography academic achievement is the mediating variable of the relationship between family capital and geospatial thinking. In the table, direct and indirect effects accounted for 67.39% and 32.61% of the total effect, respectively (see Table 6).

Taking the family economic capital, family cultural capital, and family social capital in family capital as independent variables, a mediating model with academic achievement as the mediating variable and geospatial thinking as the dependent variable was constructed. The results (see Table 7) all show that, Family economic capital, family cultural capital, and family social capital can positively predict geographic academic achievement and geospatial thinking, and geographic academic achievement can also positively predict geospatial thinking. And the confidence intervals of the three models do not include 0, indicating that some intermediaries are established. The direct and indirect intermediaries of family economic capital are 63.45% and 36.54%, respectively, and the direct and indirect intermediaries of family cultural capital are 55.88% and

Table 5. A mediation analysis of the influence of family capital on geospatial thinking.

	On GAA				On GT			
Predictors	β	SE	t	95%CI	β	SE	t	95%CI
FC	0.129	0.013	9.59***	[0.102,0.155]	0.062	0.013	4.65***	[0.036,0.088]
GAA					0.235	0.03	7.93***	[0.177,0.293]
R^2	0.083				0.102			
F	92.028				57.77			

Note: Analyses conducted using PROCESS model 4. N = 1018. GT, geospatial thinking; GAA, geography academic achievement; FC, family capital. ***p* < 0.01; ****p* < 0.001.

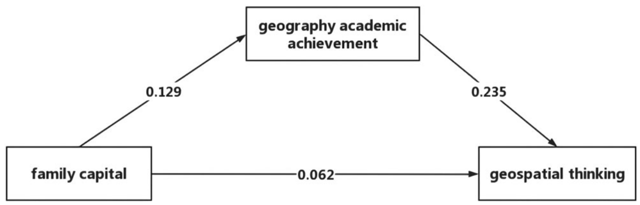

Figure 4. A structural model of factors that influence geospatial thinking.

Table 6. Total, direct effect and indirect effect of family capital on geospatial thinking.

	Effect size	Boot SE	Boot CI lower limit	Boot CI upper limit	Relative effect size
Total effect	0.092	0.014	0.035	0.089	
Direct effect	0.062	0.013	0.036	0.088	67.39%
Indirect effect	0.03	0.005	0.022	0.041	32.61%

Table 7. A mediation analysis of the influence of family economic capita, family culture capital, family social capital on geospatial thinking.

	On GAA				On GT			
Predictors	β	SE	t	95%CI	β	SE	t	95% CI
EC	0.390	0.043	9.13***	[0.306, 0.474]	0.165	0.042	3.94***	[0.083, 0.247]
GAA					0.243	0.03	8.2***	[0.185, 0.301]
R^2	0.076				0.097			
F	83.43				54.42			
CC	0.296	0.034	8.81***	[0.230, 0.362]	0.095	0.033	2.87**	[0.03, 0.159]
GAA					0.252	0.03	8.51***	[0.194, 0.310]
R^2	0.071				0.09			
F	77.53				50.43			
SC	0.164	0.027	6.05***	[0.111, 0.218]	0.11	0.026	4.30***	[0.06, 0.16]
GAA					0.252	0.029	8.70***	[0.195, 0.309]
R^2	0.035				0.099			
F	36.57				56.03			

Note: N = 1018. GT, geospatial thinking; GAA, geography academic achievement; EC, family economic capital; CC, family culture capital; SC, family social capital; FC, family capital. ****p* < .001, ***p* < .01.

Table 8. Total, direct effect and indirect effect of family economic capital, family culture capital, family social capital on geospatial thinking.

Predictors		Effect size	Boot SE	Boot CI lower limit	Boot CI upper limit	Relative effect size
EC	Total effect	0.26	0.043	0.081	0.250	
	Direct effect	0.165	0.042	0.083	0.247	63.46%
	Indirect effect	0.095	0.015	0.068	0.128	36.54%
CC	Total effect	0.17	0.033	0.030	0.160	
	Direct effect	0.095	0.033	0.030	0.159	55.88%
	Indirect effect	0.075	0.0124	0.052	0.101	44.12%
SC	Total effect	0.151	0.025	0.058	0.161	
	Direct effect	0.11	0.026	0.06	0.16	72.85%
	Indirect effect	0.041	0.008	0.027	0.059	27.15%

44.12%, respectively, the direct and indirect intermediaries of family social capital are 72.85% and 27.15%, respectively(see Table 8). Here, it is verified that the partial mediating effect of academic achievement in family capital and geospatial thinking is established. The model structure diagram is drawn according to the path coefficient, as shown in Figure 5.

Discussion

The results of this study show that family capital is positively correlated with geospatial thinking. Families with higher levels of family economic capital, family cultural capital, and family social capital have higher levels of children's geospatial thinking. Therefore, based on the results of this

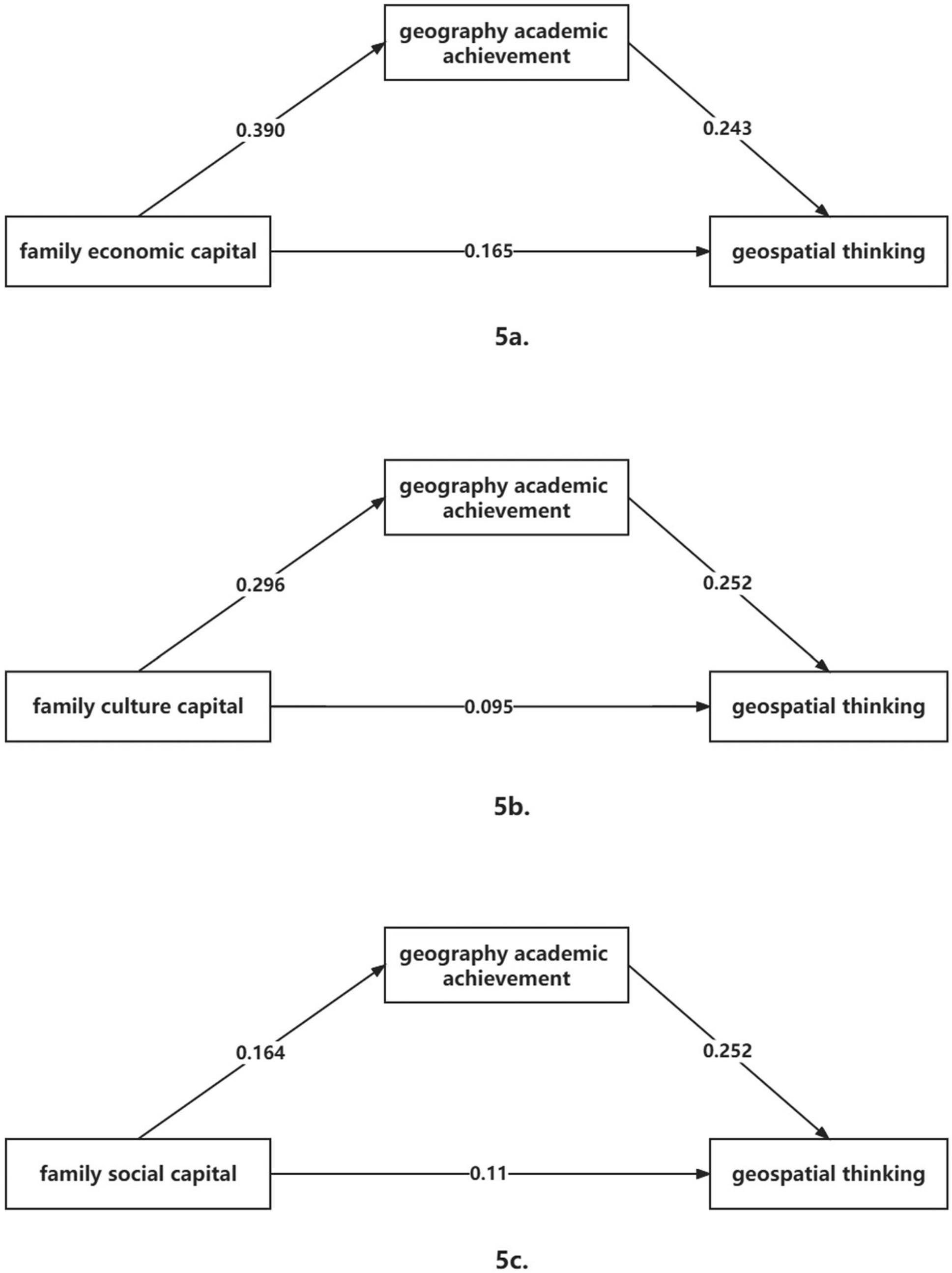

Figure 5. A structural model of factors that influence geospatial thinking_three subvariables.

study, this paper emphasizes how to improve the level of children's geospatial thinking by changing the structure of family capital consumption. In terms of the performance of family capital, the conditions that allow households to change their consumption structure and create similar essences. For example, a part of capital can be introduced into cultural consumption from other parts, and even the more difficult part can be adjusted. Increased family capital allow more opportunities for reading and visiting. It is recommended that families use the reading resources of public libraries, museums and nearby learning resources with relatively small consumption. These resources are not fundamentally different from those obtained by families with high family capital through family capital. Therefore, it is necessary to change the family consumption structure and educational philosophy of families with low family capital through the explicit form of capital of high family capital. Through frugal and efficient allocation of family capital, the same educational benefits as high family capital families can be achieved.

In the family's economic capital, within the family's own limited capital, more capital can be invested in consumption areas related to spatial issues through internal redistribution, so as to give full play to the improvement of children's spatial thinking level. For example, children from families with high family capital are more likely to use modern electronic devices such as table computers and smart phones. Parents can make full use of some spatial display functions of these electronic devices to improve children's geospatial thinking ability, such as using information in electronic mobile devices. Technical software, games, electronic maps, AR, VR, etc., this inference not only comes from the extension of the definition of family capital, but also has theoretical support from literature. For example, studies have shown that ArcGIS software (Lee and Bednarz 2009), Google Earth (Xiang and Liu 2017), electronic maps (Nielsen and Sugumaran 2011), and action games (Price et al. 2014) can all promote spatial thinking. In addition, virtual reality technology can immerse users in virtual three-dimensional space (Hauptman and Cohen 2011); Hauptman (2011) also emphasized the importance of virtual environments for cultivating students' spatial perception. Therefore, some inspiration can be drawn from these conclusions. Whether it is possible to create conditions for obtaining more capital in this form in families with low-income family capital is a unique path to solve the lack of capital and promote the development of students' geospatial thinking. This requires parents to have new theories and awareness, accessible resources and innovative paths, and may also need to endure the hardships brought about by the adjustment of the family capital structure. Of course, many parents are willing to do this for the development of their children. For example, in this survey of household economic capital, it was found that 60.88% of households own computers, 99.9% of households own mobile phones, and 65.22% of households own tablet computers. Most families have the basic conditions and only need to download relevant software on electronic mobile devices and use them in daily life and learning, so as to subtly enhance children's understanding of geographic knowledge and cognition of spatial thinking.

Second, the consumption patterns and ideas of households with high family economic capital also have an impact on geospatial thinking. For example, research shows that households with high economic capital have a higher willingness to spend on "leisure tourism" (Liu et al. 2021). Travel experience is positively correlated with spatial thinking (Euikyung, et al. 2015), it is precisely because of the travel experience created by these parents, as well as the care, companionship and cultivation of their children, that children are more likely to achieve higher academic achievement, which in turn promotes geospatial development of thinking. NATURE published a study in which Coutrot et al. (2022) measured the non-verbal spatial navigation ability of 397,162 people in 38 countries, which showed that people who grew up in rural areas had higher levels of spatial awareness. Therefore, the purpose of tourism is not about place and distance, but about students' perception of spatial knowledge, use of spatial tools, and spatial orientation in the environment (Carrera and Carlos 2016). In this process, students can combine the knowledge of space they have learned and use maps to transform two-dimensional space into three-dimensional space. Thus, during high-frequency travel experiences, children are able to capture, understand, and internalize spatial knowledge, improving their spatial thinking skills (Collins 2017; Johnson and Moore 2020).

In addition, family economic capital can also be used to directly purchase items that are conducive to cultivating students' geospatial thinking. Studies have shown that some toys with spatial attributes, such as puzzles and building blocks, can also promote the development of children's spatial thinking (Borriello and Liben 2018). Therefore, when parents buy toys, they can consciously and purposefully buy such toys as soon as possible. If limited by economic capital, parents can also make full use of waste to transform old things, such as using discarded cardboard boxes to make simple building blocks. The blocks, which are made from discarded cardboard boxes in various shapes, can be used as an affordable alternative to expensive blocks such as Lego (Figure 6). In daily entertainment, children can form an understanding of the spatial form in the process of building blocks, and can observe the spatial pattern, position change, rotation angle, etc. of objects from different perspectives, and finally realize the cultivation of children's spatial thinking ability.

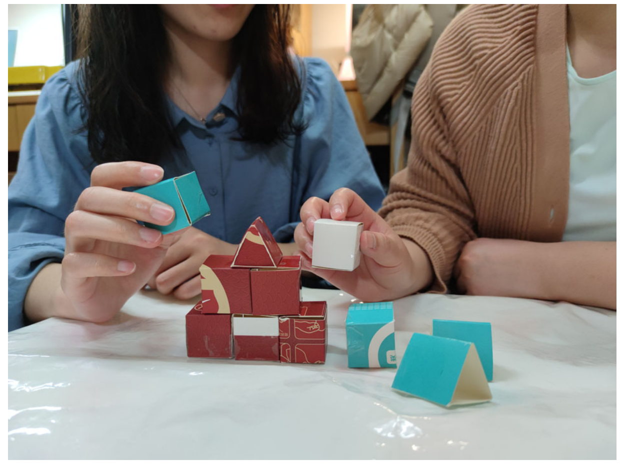

Figure 6. Building blocks made from discarded cardboard boxes.

As for family culture and social capital, different classes have different cultural methods, and the essence is not purely academic qualifications and occupations, but the cultural education methods behind them. In cultural capital, language is the carrier and manifestation of culture. Numerous studies have shown that parental use of spatial language promotes students' understanding of spatial concepts (Pruden, Levine, and Huttenlocher 2011; Borriello and Liben 2018). For example, in daily communication, tell the child to go north for 2 kilometers and turn right to enter Tibet Middle Road. In this process, fully use spatial direction words (such as above, south), spatial dimension words (such as long, thick), spatial relationship words (such as here, near), and spatial shape words (such as circle, square) to describe an object's position. In this way, students can subtly understand the meaning of spatial language, think about the relationship between objects and space, and promote the learning of future geospatial knowledge. In addition, research has found that in the process of picture book teaching, parents guide their children to pay attention to the spatial and graphic relationships in the book when accompanying their children to read, which helps children to establish spatial awareness (Szechter and Liben 2004). So sometimes education just needs to go further. It is only necessary to guide children to make relevant spatial observations in reading with children or in daily life, thereby prompting children to think and pay attention to neglected spatial relationships.

In social capital, the occupational attributes of parents also affect children's geospatial thinking. Research shows that people in industries such as science, technology, engineering, and mathematics have stronger spatial thinking skills (Wai, Lubinksi, and Benbow 2009; Holly 2013). For example, parents engaged in geography-related education can introduce the geographic location of a country to their children in their daily life, and railway staff can answer the location of cities along the railway line for children, which helps students to form a geographic understanding of geographic location and so on. This knowledge also helps students build spatial awareness of the distribution of different cities. Parents who are engaged in science, technology, engineering, mathematics and other related occupations in home education should strengthen their professional advantages and communicate with their children on topics such as direction, space, and structure in daily communication. If not parents in these occupations, the results of this study shed some light. Parents can use the characteristics of these occupations to guide their children to pay attention to the spatial position, structure, and relationship in life and learning in the process of daily communication. Therefore, by analyzing the relationship between culture, social capital and spatial thinking, it is possible to transcend the limitations of cultural and social capital and achieve more meaningful education.

Limitations and future directions

This study has several limitations. First, as a cross-sectional study, it only reflects the relationship between geospatial thinking and family capital in a specific period. Second, although the sampling method we adopted in this study has scientific basis and rationality, the effect of expanding or expanding the sample size needs further verification. Finally, this study only measures the level of family capital from the perspective of the unique characteristics of family capital, such as parents' occupation and income, but does not consider the underlying factors behind family capital, such as parental companionship and family upbringing. In the discussion part, however, the way of reviewing the literature to explore the impact of the underlying factors behind family capital on geospatial thinking suggests lack a certain degree of evidence. Therefore, our method needs to be further fine-tuned, indicating areas and directions for future research. The method of dynamically tracking and zooming in and out of the sample during the sample selection process can also be used to test the reliability of the scale. In future research, interviews with student families could be conducted to enhance the depth and breadth of family capital measures.

Conclusion

In this study, we explore the relationship between family capital and geospatial thinking and the mediating role of academic achievement in geography. The results show that the higher the level of family capital, the stronger the students' geospatial thinking ability. In addition, geographic academic achievement plays a partial mediating role between family capital and geospatial thinking. On the one hand, various dimensions of family capital can directly affect geospatial thinking; on the other hand, various dimensions of family capital first affect geographic academic achievement, and then geographic academic achievement and then have an impact on geospatial thinking. Through the results of this research, this paper provides educational inspiration for parents, guides families to appropriately change the consumption structure and educational concept, and finally achieves the same educational benefits as high-capital families through frugal and efficient family capital allocation and improves children's geographical location level of spatial thinking.

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