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Verification of the model of geographical synthetic thinking teaching behavior by Chinese geography teachers based on the TPB

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ABSTRACT

Geographical synthetic thinking—mandated by the China's "General Senior High School Geography Curriculum Standards" as one of the discipline's four core literacies—remains difficult to translate into classroom practice. Drawing on The Theory of Planned Behavior (TPB) , the dominant social-psychological model of behavioral explanation and prediction, we extended the framework by positing a direct path from subjective norms (SN) to behavioral attitude (BA). Self-report data collected from 82 teachers were analyzed with path analysis. While most hypothesized relationships were supported, the SN to behavioral intention (BI) and perceived behavioral control (PBC) to behavior links were non-significant. These findings nuance the boundary conditions of TPB in pedagogical contexts and offer evidence-based guidance for both pre-service and in-service programmes aiming to foster students' geographical synthetic thinking.

1. Introduction

1.1. Background: The relationship between geographical synthetic thinking and systems thinking

The significance of systems thinking in geographical education is widely acknowledged (Cox, 2018; Mehren & Rempfler, 2022). It foregrounds wholes over parts, traces inter-relationships, and tracks change across time and space (Lee et al., 2019; O'Connor & McDermott, 1997; Senge, 1990). National curricula increasingly list it as a learning outcome and as a lever for education for sustainable development (Fanta et al., 2019; Rempfler & Uphues, 2012; Schuler et al., 2018; Yoon & Hmelo-Silver, 2017), and classroom studies confirm that geography lessons can advance students' systems thinking (Assaraf & Orion, 2005; Cox et al., 2019; Raath & Hay, 2019; Riess & Mischo, 2010).

However, systems thinking, as a universal cognitive skill (Huang et al., 2024; Verhoeff et al., 2018), lacks inherent spatial, regional or specific disciplinary attributes. In contrast, geography is concerned with explaining the characteristics of places and the distribution of people, features, and events as they occur and develop across the Earth's surface, particularly through the lens of human-environment interactions ins specific places and locations (International Geographical Union, 1992). Explaining place-based, human-environment patterns therefore requires a disciplinary-specific synthesis that integrates factors, processes, and scales. China's geography curriculum standard labels this literacy "geographical synthetic thinking" and defined it as the way people use a synthetic perspective to understand the geographical environment. It manifests specifically through three comprehensive dimensions: factor synthesis, spatiotemporal synthesis, and regional synthesis, which can be further subdivided into six subcategories, all of equal importance (Lu et al., 2022; Ministry of Education of the People's Republic of China, 2018), as illustrated in Table 1. In essence, geographical synthetic thinking represents systems thinking reoriented through geography's unique spatial, temporal, and regional perspectives. This mode of thinking is epistemologically distinct from comprehensive analysis in other disciplines, which often focuses on internal system structures (Potash, 1994; Verhoeff et al., 2018). Rather, it achieves holism by systematically interpreting phenomena through the conceptual triad of time, space, and region, thereby providing a necessary framework for addressing complex geographical issues such as climate change, resource management, and urbanization.

1.2. Geographical synthetic thinking teaching behavior

Teacher practice is the strongest in-school driver of student learning (Hattie, 2009; Maulana et al., 2017). The development of students'

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Table 1
Subdivided categories of geographical synthetic thinking.

Dimensions	Subdivided categories	Connotation
Factor synthesis	Geographical factors systemic thinking	Know the multiple factors contained in natural and socioeconomic factors, and be able to establish the habit of thinking about geographical events from the perspective of geographical factors, and at the same time have the awareness of the leading factor.
	Geographical factors interaction thinking	Know that geographical factors are interconnected, restrictive and infiltrative, and have the awareness of connection between geographical factors.
Spatiotemporal synthesis	Temporal changes thinking	Know that geographical events and geographical factors will evolve over time, and have dynamic thinking about the evolution of geographical events and geographical factors.
	Regional differentiation thinking	Know that there are differences between geographical elements in different regions.
Regional synthesis	Intra-regional synthetic thinking	Know that the geographical factors in the region form regional geographical characteristics through interaction and mutual influence.
	Inter-regional synthetic thinking	Know that the outer region as a special geographical factor has an impact on the formation of the geographical characteristics of the region.

geographical synthetic thinking is significantly shaped by specific teaching behaviors in the classroom. Since geographical synthetic thinking was enshrined as a core literacy in 2018, many teachers have yet to embed it in daily lessons; consequently, students' geographical synthetic thinking remains weak. Empirical demonstrations are, however, promising: when teachers explicitly guide classes to build geography-specific mind maps, measurable geographical synthetic thinking gains appear after only four to five lessons (Huang et al., 2024). Similarly, Ma and Lu (2024) demonstrated that a four-lesson intervention using geographical causal diagrams significantly improved students' grasp of geographical interrelationships, a component of geographical synthetic thinking.

These finding confirm that the explicit teaching behaviors can effectively observed, diagnosed, and evaluated students' geographical synthetic thinking. Accordingly, we define geographical synthetic thinking teaching behavior as the explicit verbal behavior of teachers during geography instruction, aimed at fostering students' geographical synthetic thinking , equipping them with a comprehensive, systematic, and dynamic cognitive framework for understanding the geographical environment and its relationship with human activities (Wang et al., 2020).

1.3. TPB and elements of planned behavior in teaching geographical synthetic thinking

TPB, widely regarded as the most mature theory of behavior, was developed by Ajzen (1991) as an extension of the Theory of Reasoned Action (TRA; Fishbein & Ajzen, 1975). TRA posits that behavioral intention (BI) directly influences behavior and is shaped by behavioral attitude (BA) and subjective norm (SN). Ajzen (1991) incorporated perceived behavioral control (PBC) to address TRA's limitations in explaining behaviors not fully under volitional control. As shown in Fig. 1 (Ajzen, 2006a), perceived behavioral control (PBC) encompasses external factors such as opportunities and resources. TPB aims to explain and predict behavior: more favorable behavioral attitude (BA), stronger subjective norm (SN), and greater perceived behavioral control (PBC) strengthen behavioral intention (BI), thereby increasing the likelihood of actual behavior (Ajzen, 1991). A meta-analysis by Armitage and Conner (2001) supports TPB's validity, showing that these three components explain 27 % of behavioral variance and 39 % of intention variance.

TPB has been applied across various educational settings and is often employed to deconstruct the psychological drivers behind key educational behaviors. For instance, Cooper et al. (2016) used TPB to analyze the behavioral intention (BI) and behavior of teachers, students, and others. In a related study, Yan and Sin (2014) employed structural equation modeling within the TPB framework to explain and predict teachers' behavioral intention (BI) and behaviors regarding inclusive education. Their findings indicted that TPB effectively fit the data, with factors such as teachers' behavioral attitude (BA), subjective norm (SN), and perceived behavioral control (PBC) significantly predicted teachers' behavioral intention (BI) to adopt inclusive education. Additionally, Teo et al. (2011) demonstrated that behavioral intention (BI) was significantly influenced by behavior attitude (BA) and perceived behavioral control (PBC), with extended TPB explaining 58.5 % of the variance in teachers' behavioral intention (BI) to teach financial literacy in Singapore.

However, existing research has predominantly focused on established or Western educational contexts. This study extends the

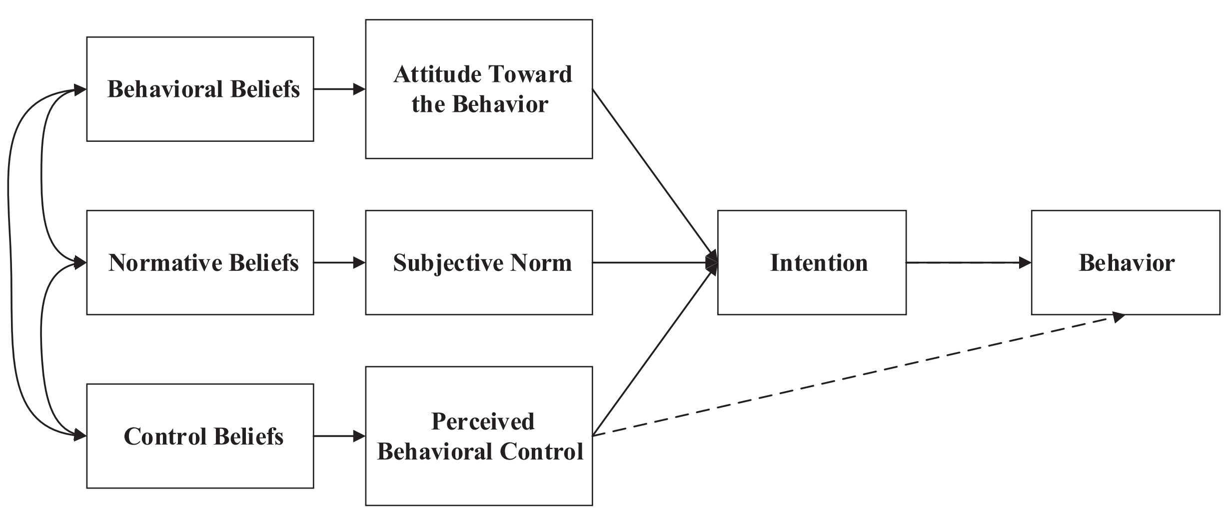

Fig. 1. TPB pattern diagram.

application of the well-established TPB to the unique and dynamic context of the initial phase of China's new curriculum reform. Fang's (2021) pioneering work first introduced the TPB into research on geographical synthetic thinking. However, the model employed remained relatively simplified and did not fully explore the deeper cognitive structure of TPB. This study moves beyond the traditional approach of focusing solely on direct determinants to instead conduct an in-depth analysis of their underlying belief foundations. By constructing a comprehensive multi-level TPB model that incorporates these beliefs, this research is able not only to identify which factors influence teachers but also to diagnose why these factors exert their influence.

We have defined the key constructs within our research framework:

Behavioral intention (BI): Reflects an individual's readiness to engage in a behavior (Fishbein & Ajzen, 2010). In this context, it refers to geography teachers'willingness to integrate this approach into their instructional practices. For example, I plan to design a related lesson in the coming month.

Behavioral attitude (BA): the tendency to respond with some degree of favorableness or unfavorableness to a psychological object (Fishbein & Ajzen, 2010). Here, it refers to geography teachers believing it is beneficial to teach geographical synthetic thinking teaching. For instance, as I prepare to design such a lesson next month, I maintain a positive attitude.

Subjective norm (SN): The individual's perception of specific behavior, shaped by the influence of important people and reflecting overall social pressure (Fishbein & Ajzen, 1975) , comprising:

➢ Injunctive norm: Perceptions concerning what should or ought to be done concerning performing a given behavior (Fishbein & Ajzen, 2010). Here, it reflects that geography teachers ought to exhibit geographical synthetic thinking teaching behavior in line with the expectations of leaders, colleagues and other salient referents. For example, my leaders believe me to design a geography lesson focused on teaching geographical synthetic thinking next month.
➢ Descriptive norm: Perceptions that others are or are not performing the behavior in question (Fishbein & Ajzen, 2010). Here, it captures whether most of the teacher's significant others themselves perform GST teaching. For example, my important geographical colleagues can design a such lesson.

Perceived behavioral control (PBC): The extent to which people believe they can perform a given behavior (Fishbein & Ajzen, 2010). In this context, it is the ability of geography teachers to believe that they can control their performance of geographical synthetic thinking teaching behavior. For instance, time constraints hinder my ability to design a such lesson for next month.

Behavioral beliefs (BB): Reflect individuals' confidence in behavioral attitude (BA) and represent cognitive structure underlying behavioral attitude (BA); the two are positively related (Fishbein & Ajzen, 2010). Here, they are the judgment of geography teachers on the firmness of their attitude toward geographical synthetic thinking teaching behavior. According to Fishbein's attitude expectation value model (Feather, 1959, 2021), behavioral beliefs (BB) are measured by multiplying two parts:

➢ Behavioral belief strength: The judgment of the firmness of behavioral attitude (BA). Here, for example, next month, I am capable of designing a such lesson.
➢ Outcome evaluation: The value judgment generated by the results of the behavioral attitude (BA). Here, for example, design a such lesson next month will be beneficial for my future teaching.

Normative beliefs (NB): An individual's perception of social normative pressures, reflecting the extent to which significant others approve or disapprove of performing a specific behavior (Fishbein & Ajzen, 2010). They comprise two additive components:

➢ Injunctive normative belief: Individuals' perception of social normative pressures. In this context, it refers to geography teachers' perception of social normative pressures to teach geographical synthetic thinking, as exerted by significant referents. It is measured as the product of:
■ Injunctive normative belief strength: The degree to which an individual believes that significant others expect he or she to perform a particular behavior (e.g., "My family believes I should design such a lesson next month").
■ Motivation to comply: The degree to which an individual is willing to conform to the expectations of significant others (e.g., " I really want to do what my family thinks I should do").
➢ Descriptive normative belief: The degree to which an individual identifies with others that they should or should not perform this behavior, calculated by multiplying two components:
■ Descriptive normative belief strength: The degree to which an individual anticipates that an important person or group will perform a particular behavior (e.g., "The head of the geography department designs at least one such lesson per month").
■ Identification with the referent: The degree to which an individual imitates a particular behavior performed by a significant person or group (e.g., " I am willing to follow what the head of the geography department does").

Control beliefs (CB): The factors that facilitate or hinder an individual's performance of a behavior (Fishbein & Ajzen, 2010). Here, they refer to geography teachers' beliefs about the factors that may facilitate or hinder the implementation of geographical synthetic thinking teaching behavior. They include two components:

➢ Control belief strength: The intensity of an individual's cognition that may control the presence of factors that carry out the behavior (e.g., "I anticipate that there will be numerous family matters next month").
➢ The power of the control factor: The intensity with which an individual perceives that these factors promote or hinder behavior (e.g., "I know that the amount of my family matters will directly affect my ability to design a such lesson next month"). The composition of behavioral beliefs (BB), normative beliefs (NB), and control beliefs (CB) is shown in Table 2.

2. Research model and hypotheses

The cultivation of geographical synthetic thinking inherently involves multidisciplinary knowledge, necessitating collaborative design within teaching-research groups. Consequently, teachers' intentions and behaviors are shaped not only by personal attitudes but are also profoundly constrained by collective peer expectations and tangible resource availability—contextual factors well-articulated through the lens of TPB. Prior research indicates that the positive behavioral attitude (BA), rooted in strong behavioral beliefs (BB), is crucial drivers of their behavioral intention (BI) to enact effective teaching practices (Okwilagwe, 2012; Said & Ishak, 2024). Furthermore, the influence of colleagues and leadership, representing subjective norm (SN), is evident in the expectation for teacher leaders to provide pedagogical models

Table 2
Composition of BB, NB and CB.

BB		Behavioral belief strength
		Outcome evaluation
NB	Injunctive normative belief	Injunctive normative belief strength
		Motivation to comply
	Descriptive normative belief	Descriptive normative belief strength
		Identification with referent
CB		Control belief strength
		Power of control factor

(Brysch & Boehm, 2014). Similarly, resources and teacher preparedness, key components of perceived behavioral control (PBC), affect their behavioral intentions, as seen in the adoption of technologies like GIS (Demirci, 2009).

Some empirical studies have shown that subjective norm (SN) does not significantly increase the prediction of behavioral intention (BI) (Alshalawi, 2022; Armitage & Conner, 2001), or that subjective norm (SN) has no direct influence on behavioral intention (BI), but rather influence it indirectly through the mediating variable of behavioral attitude (BA) (Ajzen & Driver, 1992; Chang, 1998). To address this gap and achieve a more nuanced theoretical model, this study incorporates a pivotal extension: the path from subjective norm (SN) to behavioral attitude (BA). This is supported by the concept of "norm internalization" (Oliver & Bearden, 1985). This concept originates from broader social psychological theory, which posits that external social expectations can be absorbed and integrated by individuals into their own value systems, thereby shaping their personal attitudes (Kelman, 1958). Researchers (Lee et al., 2004; Oliver & Bearden, 1985; Zhou et al., 2014) also have demonstrated that subjective norm (SN) directly impacts behavioral attitude (BA). Therefore, this study hypothesizes that the influence of subjective norm (SN) on teachers' behavioral intention (BI) stems primarily not from direct social pressure, but rather through the mediating pathway of shaping their positive teaching attitudes. Simultaneously, out of respect for the original TPB framework and consideration that a direct effect may still exist under certain circumstances, we have retained the direct path from subjective norm (SN) to behavioral intention (BI) in the model. This allows the data to test whether the mechanism of subjective norm's influence in this specific context is predominantly indirect, or if both direct and indirect effects coexist.

Based on the literature on geographical teaching practices and empirical studies of TPB, a model hypothesizing the factors influencing the geographical synthetic thinking teaching behavior of geography teachers is proposed, as shown in Fig. 2. The hypotheses are as follows:

H1. Geography teachers' behavioral intention (BI) will be positively associated with their geographical synthetic thinking teaching behavior.

H2. Geography teachers' perceived behavioral control (PBC) will be positively associated with their geographical synthetic thinking teaching behavior.

H3. Geography teachers' behavioral attitude (BA) will be positively associated with their behavioral intention (BI) in teaching geographical synthetic thinking.

H4. Geography teachers' subjective norm (SN) will be positively associated with their behavioral intention (BI) in teaching geographical synthetic thinking.

H5. Geography teachers' perceived behavioral control (PBC) will be positively associated with their behavioral intention (BI) in teaching geographical synthetic thinking.

H6. Geography teachers' subjective norm (SN) will be positively associated with their behavioral attitude (BA) in teaching geographical synthetic thinking.

H7. Geography teachers' behavioral beliefs (BB) will be positively associated with their behavioral attitude (BA) in teaching geographical synthetic thinking.

H8. Geography teachers' normative beliefs (NB) will be positively associated with their subjective norm (SN) in teaching geographical synthetic thinking.

H9. Geography teachers' control beliefs (CB) will be positively associated with their perceived behavioral control (PBC) in teaching geographical synthetic thinking.

3. Method

3.1. Research sample and data collection

Ethical considerations. The Human Subject Protection Committee of East China Normal University approved the study, and the ethical review approval number is HR 332–2020. The process for recruiting participants adhere to ethical standards.

Recruitment targets. The recruitment targets consist of secondary school geography teachers, including those from both junior high and senior high schools. During the recruitment process, there are no restrictions on the educational level of the participating teachers. Randomness ensures the distribution of teachers from both junior high and senior high schools, thereby enhancing overall representativeness.

Sample target size calculation. The sample size determination is based on the scale items and indicators pertinent to structural equation modeling. According to the rule of thumb, which take into account the reliability and validity of the measurement scale, the sample size (n1) is determined by multiplying the number of items in the subscale with the highest item count by a factor ranging from 5 to 10. Given that both the subscales for behavioral beliefs (BB) and control beliefs (CB) subscales comprise 16 items each, the resulting sample size is estimated to between 80 and 160, or potentially higher. The statistical technique employed in this analysis is path analysis, which necessitates a specific sample size. Prior research indicates that the sample size can between 5 and 20 times the estimated number of factors (Qu et al., 2005). In this study, which involves 8 variables, a preferred sample size (n2) would therefore range from 40 to 160 or more. By considering the sample sizes from both indicators (n1 and n2), a minimum sample size of 80 is deemed appropriate. Given the extensive nature of the survey, a final target sample size of 120 is recommended.

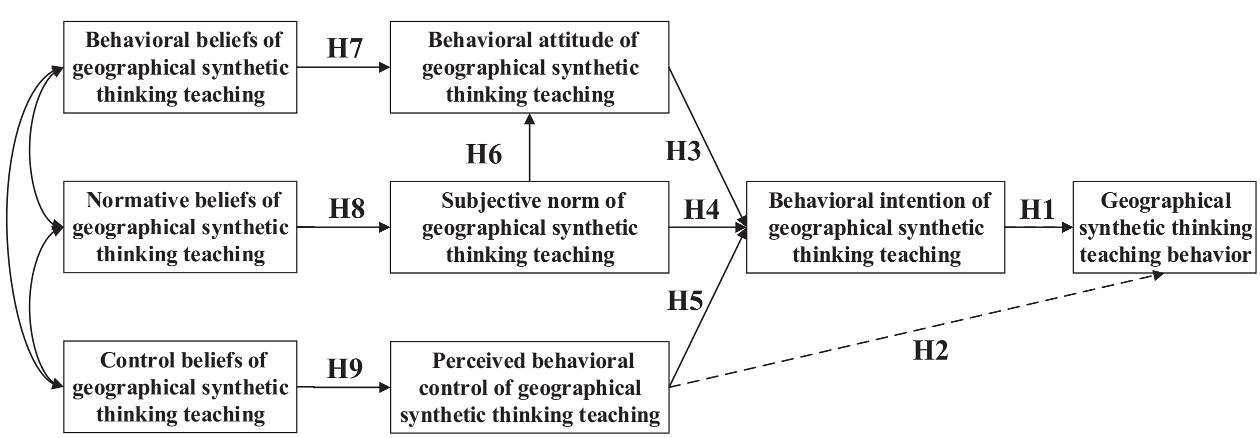

Fig. 2. Research model.

Determination of sampling provinces and cities. Using the method of stratified sampling, eight provinces—namely Shanghai, Guangdong, Shandong, Hunan, Xinjiang, Sichuan, Jilin, and Shanxi—were chosen based on criteria related to socio-economic and cultural development, as well as regional spatial balance. To identify the sampling cities, three cities representing varying levels of economic development were selected from each province, based on the ranking of "per capita GDP level" as reported in the respective statistical yearbook for 2019 or 2020. This methodology resulted in a comprehensive sample of 24 cities across the nation. The details of the "Cities/Districts" are provided in Table 3.

Allocation of provinces and cities for the sample size. The sample size allocation method for the 120 planned participants involved two steps. First, the permanent population figures of the eight sampled provinces were sourced from the China Statistical Yearbook 2020. The proportion of each province's population in relation to the aggregate population of the eight provinces was computed. Utilizing these proportions, the sample size of 120 planned participants was distributed among the provinces. Next, the permanent resident population data of the three sampled cities within each province was extracted from the respective provincial statistical yearbooks (2020). The proportion of each city's population relative to the total population of the three cities was calculated. These proportions facilitated the allocation of the provincial sample size to the three cities, culminating in the final distribution presented in Table 3 under "Planned Sample Size per City."

Sample recruitment and number of applicants. First, the recruitment information was initially disseminated via the project website, included essential project details and the anticipated responsibilities of participants. The website also displayed the ethical review approval letter and outline the associated risks and benefits of participation. Nest, online social media platforms were employed to promote recruitment efforts, specifically targeting geography teachers across a sample of 24 cities with 8 provinces. The recruitment platform established a quota for participant numbers, and typically, applications exceeding the predetermined limit for each city were not accepted. Participation was based on a voluntary principle, with applicants required to sign an electronic informed concurrently with their application. From December 11 to December 23, 2021, a total 107 geography teachers who expressed willingness to participate and met the recruitment criteria were recruited, with their provincial distribution detailed in Table 3 under " The number of samples recruited."

Questionnaires were distributed on January 14, 2022. Paper questionnaires and souvenirs were sent to 107 selected teachers, followed by survey training videos and electronic questionnaires in platform for recycling responses. Concurrently, the participating teachers received guidance on the survey process, which involved three steps: initially, they were instructed to view the training video; subsequently, they were to complete the paper questionnaire; and finally, they were required to enter their responses into the electronic questionnaire platform.

View the training video. Participants were required to view a training video designed to elucidate how teachers can evaluate alignment of their instructional practices with "geographical synthetic thinking teaching behavior". TPB requires that the behavior under study is accurately defined and measured to ensure a consistent understanding of the behavior exhibited by the sample (Fishbein & Ajzen, 2010). To maintain conceptual clarity, the operational definition of geographical synthetic thinking teaching behavior was explicitly defined as the ability to analyze geographical environments through at least one dimension of the seven dimensions of geographical synthetic thinking, to implement it comprehensively, and to consciously guide students in developing this thinking. The questionnaire included Table 4, which outlines the five-level evaluation criteria for geographical synthetic thinking teaching behavior. Prior to completing the questionnaire, participants were required to view the training video, which addressed the following components:

(1) Key definitions of geographical synthetic thinking and geographical synthetic thinking teaching behavior;
(2) Detailed grading criteria (as presented in Table 4);

Geographic case examples corresponding to Levels 1–5. The video emphasized that teachers' self-assessment of geographical synthetic thinking teaching behavior must align with these established criteria. Instructional behaviors meeting Level 3 or higher in Table 4 were recorded as valid instances of geographical synthetic thinking teaching

Table 3
Sampled economic and population information of 8 provinces and cities at the end of 2019 or 2020.

Serial number	Province	City/District	The number of samples planned to be recruited by each city	The number of samples that the provinces plan to recruit	The number of samples actually recruited	The number of samples actually returned	The actual number of valid samples in each city
1	Shanghai	Huangpu District	1	6	7	7	1
2		Minhang District	4				4
3		Chongming District	1				2
4	Guangdong	Shenzhen	20	31	16	15	5
5		Maoming	7				7
6		Meizhou	4				2
7	Shandong	Qingdao	10	25	24	21	8
8		Weifang	9				7
9		Liaocheng	6				4
10	Hunan	Changsha	8	16	11	10	6
11		Hengyang	6				1
12		Xiangxi Tujia and Miao Autonomous Prefecture	2				0
13	Xinjiang	Kelamayi	1	6	8	5	1
14		Urumqi	3				3
15		Hotan prefecture	2				1
16	Sichuan	Chengdu	15	21	20	15	11
17		Suining	3				2
18		Bazhong	3				1
19	Jilin	Changchun	3	6	9	6	4
20		Jilin	2				1
21		Siping	1				0
22	Shanxi	Taiyuan	4	9	12	12	4
23		Changzhi	2				5
24		Yuncheng	3				2
	Total		120	120	107	91	82

Table 4
Correspondence table of geographical synthetic thinking teaching behavior and grade evaluation.*

Behavior level (Quality points)	Comprehensive performance (Guide students to form geographical synthetic thinking)	Intrinsic performance	Teaching awareness	Teaching behavior	Identify
5	On the basis of level 4, the teacher can also say things like "This kind of thinking is part of geographical synthetic thinking we need to master."	Directly	Strongly	Direct performance	Yes
4	On the basis of level 3, the teacher clearly tells students that this kind of thinking for analyzing or understanding the geographical environment is a specific dimension within the seven dimensions of geographical synthetic thinking.	Obviously	Obviously	Obvious performance	Yes
3	Teachers analyze or understand the geographical environment using one or more of the seven dimensions of geographical synthetic thinking. The application of geographical synthetic thinking is complete, and teachers consciously guide students to use geographical synthetic thinking.	A little	Presence	Basically present	Yes
2	Teachers analyze or understand the geographical environment from one or more of the seven dimensions of geographical synthetic thinking. The application of geographical synthetic thinking is complete, but teachers do not consciously guide students to use geographical synthetic thinking.	A little	No	Looming present	No
1	Teachers analyze or understand the geographical environment from one or more of the seven dimensions of geographical synthetic thinking, but the application of geographical synthetic thinking is not complete. Teachers do not guide students to use geographical synthetic thinking.	only the basics	No	No	No

* Geographic factors system thinking emphasizes the comprehensiveness of factors more, hence the dominant geographic factors thinking is singled out from geographical factors system thinking as a dimension, and a total of 7 dimensions are divided.

behavior.

Investigative mobilization. The training video instructed teachers to conscientiously participate in the study. Specific survey procedures were emphasized: participants were required to initially complete a paper-based questionnaire in a quiet environment, allowing for sufficient time to respond. Subsequently, their answers were manually transcribed into an electronic survey platform. This dual-method approach, incorporating both paper and electronic formats, was designed to enhance data quality. The paper questionnaires served two primary functions:

(1) Formalizing Participation: The tangible distribution of materials reinforced the study's rigor, thereby encouraging respondents to engage with the process earnestly.
(2) Cognitive Engagement: By allowing teachers to thoroughly review questions and contemplate their responses while holding the paper form, thereby enhancing answer accuracy.

Questionnaires collection and validity screening. A total of 91 questionnaires were collected through the Questionnaire Star platform, resulting in an 85.0 % response rate. The provincial distribution of the valid samples is presented in Table 3 ("Number of Samples Actually Returned"). To assess the level of authenticity of the responses, five validity-check items (items 26, 35, 50, 58, and 67) were scrutinized, with response options ranging from bad (1) to good (7). These items were deliberately designed around two principles: first, to detect social desirability bias by describing behaviors strongly contrary to teacher professional ethics (e.g., "playing with your phone while teaching students in the classroom"), observing whether respondents endorsed behaviors highly unlikely to be accepted by genuine teachers; second, to assess factual plausibility by presenting objectively unreasonable or teaching-irrelevant statements (e.g., "sunbathing will affect your geographical synthetic thinking teaching behavior"), evaluating respondents' attentiveness. All items used a 7-point Likert scale, and a predefined exclusion criterion was applied: participants who provided responses that were both implausible and violated professional norms (i.e., selecting ratings of 5, 6, or 7) on two or more items were deemed invalid. Based on this criterion, nine participants were ultimately excluded, significantly enhancing the internal validity of the data.

Valid sample size and distribution. Out of the 91 samples collected, 9 were classified as invalid and subsequently excluded, yielding a total of 82 valid responses. This resulted in an effective response rate of 90.1 %. The valid samples were distributed across 22 cities within 8 provinces. It is noteworthy that no samples were collected from Xiangxi in Hunan Province or Siping in Jilin Province. The specific provinces and cities from which valid samples were obtained are outlined in Table 3, which is titled in " The actual number of valid samples in each province " and " The actual number of valid samples in each city." To ensure the reliability of the measurement instrument, this study conducted reliability analysis on the scales of key variables. The results showed that the Cronbach's alpha coefficients for all constructs exceeded the acceptable threshold (0.7), with specific values presented in Table 5. This indicates that the scales used in this study possess good consistency and reliability. Table 6 presents statistics concerning the educational qualifications, teaching experience, school levels, and the frequency of teaching and research activities of the respondents.

Data analysis method. Data analysis utilized path analysis within structural equation modeling, employing AMOS 24.0 and maximum likelihood estimation for hypothesis testing. The fit of empirical data to the models was evaluated using the key model fit indicators, including χ^2、χ^2/df, RMSEA, GFI, IFI, NFI, TLI, and CFI (Kline, 2005).

3.2. Measurement tools

The measurement tool was developed based on regarding standard questionnaires derived from the TPB model, as outlined provided by Fishbein and Ajzen (2010) and Ajzen (Ajzen, 2006a, 2006b). In November 2021, six senior high school geography teachers and one junior high school geography teacher were selected to provide consultation and input for the design process. Following several revisions and enhancements, expert consultations were conducted to evaluate the appropriateness of the selected questionnaire content. On February 16, 2022, an assessment of the scale's content validity was carried out by one associate professor from a university, two graduate students

Table 5
Reliability analysis.

Construct		Cronbach's alpha	Meets Threshold (>0.7)	Number of Items
Full Scale		0.974	Yes	65
BE	Behavior	0.762	Yes	3
BI	Behavioral Intention	0.784	Yes	3
BA	Behavioral Attitude	0.925	Yes	4
SN	Subjective Norm	0.878	Yes	6
PBC	Perceived Behavior Control	0.861	Yes	4
BB	Behavioal Beliefs	0.947	Yes	16
NB	Norm Beliefs	0.895	Yes	13
CB	Control Beliefs	0.927	Yes	16

Table 6
Educational qualifications, teaching experience, school levels, and the frequency distribution of teaching and research activities of the respondents.

Educational qualification	junior college	Undergraduate course	Master	Doctor
	0	56	25	1
Teaching experience	0–5 year	6–10 year	11–15 year	>15 year
	29	16	8	29
School level	The top	Second level	Third level	Normal
	13	22	23	24
Frequency of teaching and research activities	More	Some	Less	Few
	20	43	12	7

specializing in geography education, and two secondary school geography teachers with expertise in the TPB. The findings indicated that the content validity of all measured items exceeded 0.8, yielding an overall content validity of 0.96 for the scale, indicative of high validity. As a result, a formal questionnaire was established. Based on the aforementioned design process and expert consultations, the reliability of the questionnaire was ensured, culminating in the finalization of the formal questionnaire.

Due to the difficulty of directly observing the frequency of teachers' geographical synthetic thinking teaching behavior, as well as the long time and cost of observation (Fishbein & Ajzen, 2010), all questionnaires were designed as self-reports. Each study variable was operationalized through a range of 3 to 16 items, culminating in a total of 75 items. The initial five items were designed to collect basic information about the teachers, while an additional five items were included to assess the authenticity of the responses. The remaining items encompassed various constructs, including behavior (BE), behavioral intention (BI), behavioral attitude (BA), behavioral beliefs (BB), subjective norm (SN), normative beliefs (NB), perceived behavioral control (PBC), and control beliefs (CB), distributed as follows: 3, 3, 4, 16, 6, 13, 4, and 16 items, respectively, resulting in a total of 65 items. Notably, the items pertaining to behavior (BE) and behavioral intention (BI) utilized a 5-point Likert scale, while all other items assessed using a 7-point Likert scale.

4. Results and discussion

4.1. Statistical results and analytical results

Table 7 provides an analysis of the normality, VIF values, and EVA values across eight constructs. The data distribution for each construct is normal, with skewness and kurtosis values falling within the recommended range (Kline, 2005). The level of multicollinearity is assessed using the VIF, where VIF values less than 5 indicate a low impact of multicollinearity (Hair et al., 1995). In this study, the VIF values for the constructs range from 1.74 to 3.67, thereby indicating a low level of multicollinearity.

Convergent validity can be assessed using the average variance extracted (AVE) (Fornell & Larcker, 1981), with an AVE value of 0.50 or higher deemed acceptable. As indicated in Table 7, the AVE values for all constructs in this study range from 0.58 to 0.93, thereby demonstrating satisfactory convergent validity for the proposed constructs. Discriminant validity can be evaluated by comparing the square root of the AVE value for a given construct with the correlations between that construct and all other constructs. In Table 8, which presents the inter-factor correlation matrix, the diagonal elements have been replaced with the square roots of the AVE values. Discriminant validity is considered sufficient when the diagonal elements exceed the off-diagonal elements within the corresponding rows and columns. The data presented in Table 8 clearly indicate that discriminant validity is sufficient, thereby affirming the appropriateness of the constructs within the proposed research model.

Table 9 shows the fitness between the theoretical hypothesis research model and the empirical data. GFI = 0.9 is in an acceptable state (Hair et al., 2006). All indicator values except χ^2 and RMSEA meet the recommended acceptable fitting levels. Both χ^2 (Hair et al., 2006) and RMSEA (Kenny et al., 2015) are sensitive to increases in sample size and the number of observed variables. Consequently, the χ^2/df value is selected, which ranges no more than 3:1, indicating an acceptable fit between the hypothetical model and the sample data (Carmines & McIver, 1981). The various fitting indices presented in Table 9 suggest that, while the fitting results between the hypothetical model and the actual data may not be optimal, it remains within acceptable limits.

Fig. 3 presents the results of the path model analysis, revealing that seven out of the nine hypotheses paths received empirical support. In the context of teaching geographical synthetic thinking, a significant association between behavioral intention (BI) and behavior (BE), thereby supporting H1. Additionally, both behavioral attitude (BA) and perceived behavioral control (PBC) demonstrated significant relationships with behavioral intention (BI), thus supporting H3 and H5, respectively. However, the path from subjective norm (SN) to behavioral intention (BI) was not statistically significant, indicating a lack of support for H4. This outcome aligns with previous research indicating that subjective norm (SN) lacks a clear predictive effect on behavioral intention (BI) (H4), as noted in the studies by Armitage and Conner (2001) and Alshalawi (2022). It is worth noting, however, that subjective norm (SN) showed a significant relationship with behavioral attitude (BA), thereby supporting H6. Furthermore, behavioral beliefs (BB), normative beliefs (NB), and control beliefs (CB) were found to significantly predict behavioral attitude (BA), subjective norm (SN), and perceived behavioral control (PBC), respectively, thereby supporting H7, H8 and H9. Table 10 displays a summary of the hypothetical results, path coefficients, and variance explanations within the proposed study model.

4.2. Explanation and discussion

The study indicated that behavioral intention (BI) severs as the principal predictor in the context of geographical synthetic thinking teaching behavior, accounting for 47 % of the behavioral variance. Additionally, behavioral attitude (BA), subjective norm (SN), and perceived behavioral control (PBC) collectively accounted for 39 % of the variance in behavioral intention (BI) in this context. A meta-analysis conducted by Armitage and Conner (2001) indicated that behavioral attitude (BA), subjective norm (SN), and perceived behavioral control (PBC) together explained 27 % of the behavioral variance and 39 % of the behavioral propensity variance. Thus, the classical model of the TPB is confirmed in terms of the geographical synthetic thinking teaching behavior of geography teachers.

H1 has been demonstrated that behavioral intention (BI) is a significant independent predictor of geographical synthetic thinking teaching behavior. The interpretation rate of behavioral intention (BI) for geographical synthetic thinking teaching behavior is 47 %, which significantly surpasses the 27 % derived from the meta-analysis of TPB conducted by Armitage and Conner (2001).

H2 is not supported; specifically, in the context of geographical

Table 7
Descriptive statistics.

Construct		Skewness	Kurtosis	VIF	AVE
BE	Behavior	0.51	−0.56	–	0.67
BI	Behavioral Intention	−0.28	−0.79	1.74	0.58
BA	Behavioral Attitude	−1.47	1.49	3.12	0.76
SN	Subjective Norm	−0.51	−0.57	2.31	0.60
PBC	Perceived Behavior Control	−0.37	−0.80	2.01	0.60
BB	Behavioal Beliefs	−1.01	0.08	3.04	0.73
NB	Norm Beliefs	−0.60	−0.62	3.67	0.89
CB	Control Beliefs	−0.38	−0.63	3.27	0.93

VIF: Variance Inflation Factor; AVE: Average Variance Extracted;

Table 8
Inter-factor correlation matrix.

	BE	BI	BA	SN	PBC	BB	NB	CB
BE	(0.82)							
BI	0.69**	(0.76)						
BA	0.36**	0.61**	(0.87)					
SN	0.42**	0.38**	0.58**	(0.77)				
PBC	0.44**	0.50**	0.53**	0.51**	(0.77)			
BB	0.39**	0.50**	0.73**	0.57**	0.61**	(0.86)		
NB	0.45**	0.46**	0.55**	0.72**	0.63**	0.70**	(0.77)	
CB	0.43**	0.52**	0.69**	0.62**	0.63**	0.70**	0.76**	(0.79)

** At the 0.01 level (two-tailed), the correlation is significant.

Table 9
Model suitability test table.

Indicator	Result	Standard	Adaptability
χ^2	37.791, $P = 0.002$	$P > 0.05$	×
χ^2/df	2.362	1–3	√
RMSEA	0.130	<0.05	×
GFI	0.900	>0.90	Suitable
NFI	0.914	>0.90	√
IFI	0.948	>0.90	√
TLI	0.907	>0.90	√
CFI	0.947	>0.90	√

RMSEA = root mean square error index; GFI = goodness of fit index; NFI = normed fit index; IFI = incremental fit index; TLI = tucker-lewis coefficient; CFI = comparative fix index.

synthetic thinking teaching, perceived behavioral control (PBC) does not exert a significant influence on behavior. While perceived behavioral control (PBC) is generally regarded as having a causal relationship with behavior, its insignificant effect in this study suggests a contextual adaptation of the TPB framework. Two complementary explanations merit consideration. First, when individuals underestimate the difficulty of a behavior, perceived behavioral control (PBC) fails to effectively mediate the relationship between behavioral intention (BI) and actual behavior (Dibonaventura & Chapman, 2008). Geography teachers may perceive the teaching geographical synthetic thinking as a straightforward endeavor, potentially leading them to overlook the essential resources, skills, and cognition required for effective instruction. This underestimation of behavioral complexity could weaken the mediating role of PBC between behavioral intention and actual implementation. Second, and more critically, the institutional context must be considered. When teaching reforms are strongly promoted through administrative mandates and evaluation systems, external enforcement may supersede personal control perceptions as the primary driver of behavioral execution. Under the current backdrop of China's curriculum reform, the implementation of teaching behaviors becomes organizationally mandated rather than individually controlled, potentially explaining the attenuated relationship between this path. This suggests that in highly regulated educational environments, the classical TPB model may require adaptation to account for the overpowering effect of institutional forces on teacher behavior.

H3 is supported, demonstrating that behavioral attitude (BA) significantly predicts behavioral intention (BI) within the context of geographical synthetic thinking teaching. Analyzing the path coefficients reveals that behavioral attitude (BA) has the most substantial effect on behavioral intention (BI), which aligns with the findings of the TPB meta-analysis conducted by Armitage and Conner (2001). A geography teacher's positive and accurate behavioral attitude (BA) correlates with an increased likelihood of forming a behavioral intention (BI) to teach geographical synthetic thinking. When teachers recognize the value of teaching geographical synthetic thinking and believe it will have a positive impact, they are more likely to cultivate a positive attitude toward the instruction.

H4 is not supported; that is, indicating no significant relationship

Table 10
Study results of the model hypothesis test.

Hypothesis	Path	Estimate	P	Significance
H1	BE ← BI	0.622	***	Significant
H2	BE ← PBC	0.124	0.167	Not significant
H3	BI ← BA	0.500	***	Significant
H4	BI ← SN	−0.038	0.721	Not significant
H5	BI ← PBC	0.266	0.005*	Significant
H6	BA ← SN	0.251	0.003*	Significant
H7	BA ← BB	0.594	***	Significant
H8	SN ← NB	0.716	***	Significant
H9	PBC ← CB	0.630	***	Significant

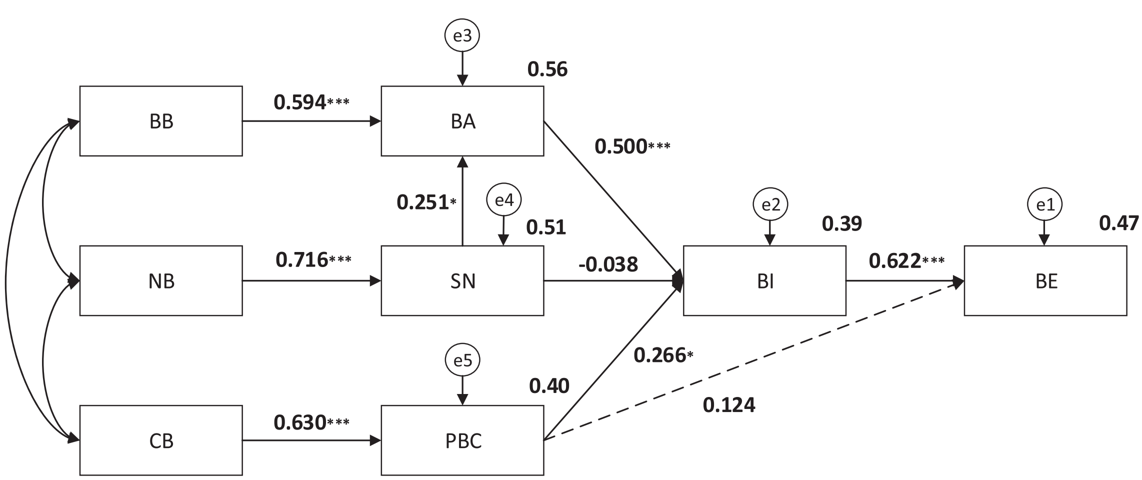

Fig. 3. A path map for the study model.

between subjective norm (SN) and behavioral intention (BI) in the context of geographical synthetic thinking teaching. Ajzen (1991) asserts that the relative role of behavioral attitude (BA), perceived behavioral control (PBC), and subjective norm (SN) in predicting behavioral intention (BI) differs in different situations. Three potential explanations for this observation can be proposed. Firstly, the overwhelming predictive strength of behavioral attitude (BA) and perceived behavioral control (PBC) in this context may have overshadowed the effect of subjective norm (SN), consistent with patterns observed in other professional settings where individual expertise is emphasized. Secondly, drawing on Teo et al. (2011) framework, the non-significant path suggests that geography teachers' decisions are driven more by individual initiative than external social pressures. This aligns with the professional autonomy typically accorded to educators in pedagogical decision-making. Thirdly, and most critically, we must consider the administrative context of educational reform. When teaching initiatives are implemented through top-down mandates, subjective norm (SN) may transform from social influences into institutional requirements. In strong administrative background such as the Chinese education system, external expectations become formal obligations rather than voluntary social compliance, potentially explaining the attenuated relationship between subjective norm (SN) and behavioral intention (BI). This transformation suggests that the classical TPB construct of subjective norm (SN) requires re-conceptualization in contexts where professional behavior is heavily regulated by administrative systems.

H5 is supported, indicating that perceived behavioral control (PBC) serves as an independent predictor of behavioral intention (BI) within the context of geographical synthetic thinking teaching. The stronger a teacher's sense of control over their geographical synthetic thinking teaching behavior, the more likely they are to develop a behavioral intention (BI). For example, when geography teachers are confident in their understanding of the curriculum standards, possess a through comprehension of geographical synthetic thinking and have the requisite resources and experience for geographical synthetic thinking teaching, their confidence in controlling their teaching behavior increase, thereby enhancing the likelihood of developing behavioral intention (BI).

H6 has been demonstrated that in the context of geographical synthetic thinking teaching, subjective norm (SN) significantly predicts behavioral attitude (BA). This indicates that subjective norm (SN) exerts an indirect linked with behavioral intention (BI) through its effect on behavioral attitude (BA). That is to say, a geography teacher's behavioral attitude (BA) toward geographical synthetic thinking teaching can be enhanced by the examples or exemplary roles of others, which may subsequently improve the teacher's behavioral intention (BI) regarding geographical synthetic thinking teaching.

H7, H8, and H9 have been validated. A comparison analysis of the findings from this study with the meta-analysis conducted by Armitage and Conner (2001), as shown in Table 11, indicates that in the context of geographical synthetic thinking teaching, three beliefs can predict behavioral attitude (BA), subjective norm (SN), and perceived behavioral control (PBC), respectively, and play a significant role.

5. Conclusions, teaching suggestions and limitations

5.1. Conclusions

The findings derived from the samples and data analysis in this study substantiate the model of factors influencing geographical synthetic thinking teaching behavior of geography teachers. The results indicate that, within the context of geographical synthetic thinking teaching, behavioral intention (BI) shows a significant association with behavior (BE). Additionally, behavioral attitude (BA), perceived behavioral control (PBC), and subjective norm (SN) all show significant relationships with behavioral intention (BI), each shaped by their respective beliefs: behavioral beliefs (BB), control beliefs (CB), and normative beliefs (NB). Notably, behavioral attitude (BA) exhibits the highest explanatory power regarding behavioral intention (BI). The analysis also reveals an indirect relationship between subjective norm (SN) and behavioral intention (BI) mediated through behavioral attitude (BA). However, the model did not confirm two hypothesized pathways: from subjective norm (SN) direcly to behavioral intention (BI) and from perceived behavioral control (PBC) directly to behavior (BE).

Table 11
The interpretation rate of the three types of beliefs.

Explanation rate	H7 (BA ← BB)	H8 (SN ← NB)	H9 (PBC ← CB)
Meta-analysis	25 %	25 %	27 %
This study	53 %*	51 %	40 %

* Both BB and SN can explain the 53 % variance change in BA.

5.2. Teaching suggestions

Drawing upon the research findings, we can formulate targeted recommendations aimed to improving teachers' instructional practices in geographical synthetic thinking by addressing behavioral attitude (BI), subjective norm (SN), perceived behavioral control (PBC), and the underlying beliefs that shape these factors.

Firstly, to improve behavioral beliefs (BB), it is advisable to implement training programs that focus on the concepts and meaning of geographical synthetic thinking. Such initiatives may involve the reading of geography books, literature and articles that address this subject, thereby highlighting the advantages of teaching geographical synthetic thinking, and fostering a positive teaching attitude that encourages the occurrence of geographical synthetic thinking teaching behavior.

Secondly, to effectively address subjective norms (SN) and normative beliefs (NB), school leaders have the opportunity to foster a constructive educational vision for teachers, thereby enhancing their professional development (Robinson et al., 2008). Additionally, the formation of a community comprising core geography teachers can capitalize on the exemplary and demonstrative functions of these educators, thereby encouraging other geography teachers to actively participate in the instruction of geographical synthetic thinking.

Thirdly, to improve control beliefs (CB), it is essential to offer both national and school-level support for teachers in the instruction of geographical synthetic thinking teaching. Such support may encompass the enhancement of practical training programs specifically aimed at geographical synthetic thinking teaching, as well as the provision of essential resources to enable teachers to deliver effective instruction in this domain.

5.3. Limitations

The study has several limitations. Firstly, this study acknowledges the implications of the small sample size for statistical power and generalizability. The limited sample size reduces statistical power, potentially failing to detect actually significant relationships between variables. And the generalizability of findings should be interpreted with caution. While targeted sampling ensured representativeness within the research context, broader validation through larger-scale studies is warranted. We recommend future research employ expanded sample sizes and cross-regional comparisons to verify the robustness of these findings.

Secondly, there are limitations associated with self-reported data and the absence of qualitative research. The model developed in this study is primarily based on theoretical deductions and quantitative research perspective; however, it is deficient in comprehensive and detailed interview research. Self-reports carries inherently limitations that cannot fully eliminate biases and inaccuracies, such as social desirability bias and self-perception errors. To complement self-reported questionnaire data, future research should incorporate direct observational methods. Structured classroom observations (live or video-recorded) using validated protocols could provide an objective measure of geographical synthetic thinking teaching behavior, thereby triangulating our findings and mitigating potential biases associated with self-report.

Thirdly, the path analysis results in this study indicate that RMSEA (Value = 0.130) did not meet the ideal standard of being below 0.05. We believe this outcome is jointly influenced by the following two factors:

On one hand, the relatively limited sample size of this study is a potential technical factor contributing to the elevated RMSEA value (Kenny et al., 2015). Therefore, given the current sample size, this index may have provided an overly conservative estimation of the model's fit. Future studies could further validate and optimize the model's fit precision by expanding the sample size.

On the other hand, and more importantly, the RMSEA value may also reflect a simplification in the theoretical model. This metric suggests that the model might have omitted a few theoretically plausible secondary paths or unexplained measurement error correlations. This does not negate the validity of the core framework of the TPB, but rather indicates that when applied to the complex professional behavior of "teaching geographical synthetic thinking," there may be certain contextual influencing factors (such as school culture, teachers' professional development experiences, etc.) that have not been fully captured. This inclusion would enhance the explanatory capacity of the study model and provide a more scientifically rigorous understanding the factors influencing the geographical synthetic thinking teaching behavior of geography teachers from a multifaceted perspective.

Furthermore, to move beyond the correlational nature of our cross-sectional data, future studies should employ longitudinal designs tracking teachers' beliefs, intentions, and actual teaching practices over an extended period (e.g., throughout a semester or a curriculum reform initiative). This would allow for a more robust examination of the causal relationships postulated by the TPB model. Additionally, intervention studies could be designed to test whether enhancing teachers' behavioral beliefs or perceived behavioral control leads to measurable changes in their teaching intentions and behaviors.

CRediT authorship contribution statement

Lei Fan: Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Lu Liu:** Writing – review & editing, Visualization, Validation, Methodology, Investigation, Formal analysis. **Xiaoxu Lu:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Data curation, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Table A
Measurement Scales and Example Items for Constructs in the TPB.

Construct		Example Item
BE	Behavior	In the previous phase, how frequently did you teach geographical synthetic thinking in your classes? (Only reaching Level 3 qualifies as having done so; otherwise, select E): A. Every class session B. Once per week C. Once every two weeks D. Once per month E. Hardly ever
BI	Behavioral Intention	In the upcoming phase, how frequently do you plan to teach geographical synthetic thinking in your classes? (Only reaching Level 3 qualifies as teaching; otherwise, select E): A. Every class session B. Once per week C. Once every two weeks D. Once per month E. Hardly ever
BA	Behavioral Attitude	For you, teaching geographical synthetic thinking in classes in the upcoming phase is: [Completely unnecessary 1: 2: 3: 4: 5: 6: 7 Highly necessary]
SN	Subjective Norm	Most people who are important to you think you ____ teach geographical synthetic thinking in geography classes in the upcoming phase: [Strongly should not 1: 2: 3: 4: 5: 6: 7 Strongly should]
PBC	Perceived Behavior Control	You are confident in your ability to teach geographical; synthetic thinking in classes in the upcoming phase: [Very unconfident 1: 2: 3: 4: 5: 6: 7 Very confident]
BB	Behavioal Beliefs	Implementing synthetic thinking instruction will ____ help students apply geographical synthetic thinking to understand geographical environments and comprehend human-environment relationships: [Extremely unlikely 1: 2: 3: 4: 5: 6: 7 Extremely likely]
NB	Norm Beliefs	Some individuals among school administrators/supervisors/teaching-research group leaders believe you ____ implement geographical synthetic thinking instruction: [Strongly should not 1: 2: 3: 4: 5: 6: 7 Strongly should]
CB	Control Beliefs	You predict that in the upcoming phase, training related to geographical synthetic thinking instruction will: [Weaken significantly 1: 2: 3: 4: 5: 6: 7 Strengthen significantly]

Data availability

Data will be made available on request.

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