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Research Article

A Comparative Study of Scientific Attitudes between Chinese and Thai Sixth-Grade Students

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ABSTRACT

Scientific attitudes are an indispensable component of scientific literacy which support scientific culture, technological development, cross-cultural cooperation, and contributing to social civilization. Educational and cultural environments are critical factors shaping students' scientific attitudes, making cross-cultural comparative research essential for optimizing science education across contexts. This study compared the scientific attitudes of 1,601 sixth-grade students (age 11–12) from urban areas of China and Thailand using a validated 25-item five-point Likert scale, focusing on five dimensions: curiosity, openness, critical thinking, collaborative spirit, and rigor. Descriptive statistics and the non-parametric Mann-Whitney U test were used to examine cross-national differences. Results showed that Chinese students had a significantly higher total score of scientific attitudes than Thai students (China: M = 92.67; Thailand: M = 90.42, $p < .05$), though the effect size was small (r = .062). At the dimensional level: no significant difference was found in curiosity ($p > .05$); no significant difference was observed in critical thinking ($p > .05$); Chinese students scored significantly higher in openness ($p < .05$), collaborative spirit ($p < .05$) and rigor ($p < .05$). Chinese students outperformed Thai peers in active knowledge acquisition, openness, data rigor, teamwork, and bias avoidance while Thai students were stronger in verify information resources. Given the vital role of scientific attitudes in fostering future researchers and innovators, future cross cultural science education cooperation between China and Thailand should integrate the strengths of both countries for enhancing students' scientific attitudes and literacy to prepare them for scientific research and global cooperation.

Keywords: Scientific attitudes, Comparative study, China, Thailand, Sixth-grade students

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Introduction

Against the backdrop of globalization and rapid technological advancement, global educational reform has shifted its core orientation from mere knowledge transmission to cultivating students' social agency, lifelong adaptability, and comprehensive scientific literacy [1, 2]. Improving public scientific literacy serves as the fundamental driving force for social civilization and sustainable progress [3]. Scientific literacy refers to students' capacity to deploy scientific concepts to interpret and resolve real-life problems, within which scientific attitude occupies an indispensable core position [4, 5].

International assessment systems including PISA and TIMSS developed by OECD and IEA have incorporated scientific attitude as a key indicator for evaluating science education quality. Existing literature confirms that scientific attitude underpins the construction of scientific culture and national technological innovation capacity; it shapes citizens' recognition and support for science, facilitates cross-cultural interdisciplinary collaboration, and predicts individuals' long-term participation in science-related learning and careers [6-9]. Cultivating positive scientific attitudes can significantly boost students' problem-solving performance and overall scientific literacy [10]. Accordingly, nurturing scientific attitudes has become a universal core objective of basic science curricula worldwide [11].

China and Thailand, two developing Asian nations, have both prioritized primary science education reform and explicitly stipulated scientific attitude cultivation as a curriculum goal. China's Compulsory Education Science Curriculum Standards (2025 Edition) frames scientific attitude as a critical component of students' core scientific literacy, highlighting the development of curiosity, rigor, and collaborative inquiry [12]. In Thailand, the Institute for the Promotion of Teaching Science and Technology (IPST) [13] also positions scientific thinking and positive scientific attitudes as primary educational targets under the Basic Education Core Curriculum (B.E. 2551).

Chinese-Thai science and human resource cooperation has deepened continuously in recent years. Joint science education programs, vocational training partnerships, and institutional memorandums of understanding between the Thailand Institute of Scientific and Technological Research (TISTR) and Chinese universities create abundant cross-cultural scientific inquiry opportunities for students, elevate teachers' instructional capacity, and optimize school research environments [14, 15]. Comparative research on students' scientific attitudes between the two countries can provide empirical evidence for collaborative curriculum design, targeted teacher training, and the construction of an inclusive cross-cultural science education ecosystem, laying a foundation for jointly cultivating innovative talents capable of addressing global technological challenges.

Culture exerts a formative influence on scientific attitudes by shaping national values, classroom pedagogical norms, and students' behavioral tendencies [16, 17]. Distinct cultural traditions separate China and Thailand: Thai society is rooted in Buddhist collectivism and the unique krengjai culture that prioritizes interpersonal harmony and respect for hierarchy, discouraging students from raising critical questions publicly; classroom instruction emphasizes hands-on practical operations and emotional interaction [18]. By contrast, Chinese education is shaped by Confucian collectivism, achievement-oriented values, and pervasive exam-driven culture, which prioritizes theoretical knowledge accuracy, academic rigor, and respect for authority. Intense competition for higher education encourages students to comply with evaluation standards while pursuing high academic engagement [19]. Such cultural divergences inevitably produce differentiated developmental characteristics in students' scientific attitudes, which science education research must fully consider to implement culturally responsive teaching [20].

Sixth grade represents a pivotal developmental window for scientific attitude research. At this final stage of primary education, children begin to form abstract logical thinking, and their scientific dispositions remain highly malleable [21, 22]. Their scientific attitudes could be one important indicator mirror the implementation quality of national primary science curricula [23, 24]. Nevertheless, existing comparative research suffers from clear limitations: cross-cultural studies mostly contrast Western and East Asian students or conduct intra-Southeast Asian comparisons [25, 26], while empirical work which systematically compared primary students' scientific attitudes between China and Thailand was not found. Most single-country investigations target middle, high school, or university participants, rarely focusing on sixth-grade primary pupils [23, 26-30]. To fill this gap, the present study selects urban sixth-grade students from China and Thailand as research subjects to compare their overall scientific attitude levels and dimensional disparities, revealing the interactive mechanisms of cultural traditions and educational systems behind attitudinal differences.

Gardner [31] articulated the foundational conceptual distinction between scientific attitudes and attitudes toward science. Scientific attitudes referred to cognitive-behavioral traits including critical thinking and evidence-based reasoning. Attitudes towards science referred to affective dispositions such as interest in science, learning anxiety, and emotional preference for scientific activities. This dual division has guided decades of subsequent scale development and empirical measurement targeting student science dispositions [32].

Rosenberg & Hovland [33] first systematically proposed the tripartite structure of general attitudes, consisting of cognitive, affective, and behavioral dimensions. This framework has become the universal theoretical basis for scientific attitude research and has been repeatedly verified and expanded by scholars across contexts: Cognitive dimension: Rational judgment and recognition of scientific knowledge, the intrinsic value of science, and standardized scientific norms (openness, rigor, collaboration) [34, 35]. Affective dimension: Emotional responses toward scientific learning, including curiosity, enthusiasm, learning anxiety, and acceptance of diverse scientific viewpoints [34, 35]. Behavioral dimension: Active participation in scientific practice, such as experimental operation, collaborative problem-solving, and evidence-based questioning [34, 35].

Many scholars supplemented additional sub-components including scientific responsibility, objectivity, emotional self-efficacy, and perceptions of scientists' social roles to adapt the model to the characteristics of authentic scientific inquiry [36, 37]. Multiple studies have further identified curiosity, openness, critical thinking, and collaboration as core observable indicators of scientific attitudes [38-40]. Brossard et al. [35] and Sekar & Mani [41] specifically emphasized curiosity and openness as core affective drivers of voluntary scientific exploration.

Integrating Gardner's dichotomy, Rosenberg's three-dimensional theoretical framework, and core evaluation elements adopted in PISA and TIMSS (inquiry, collaboration, experimental rigor), this study operationalizes scientific attitudes into five mutually inclusive, measurable dimensions covering cognitive, affective, and behavioral layers, which fit the cognitive characteristics of primary school students:

Curiosity: Willingness to explore unknown phenomena and ask questions.

Openness: Ability to accept diverse viewpoints and adjust positions based on evidence.

Critical Thinking: Questioning the reliability of scientific conclusions and evaluating evidence quality.

Collaborative Spirit: Tendency to solve scientific problems through teamwork.

Rigor: Pursuit of precision in data recording, experimental design, and conclusion derivation.

Cooperation between Thailand and China in developing human resources in science and research is vital for advancing scientific literacy and fostering positive scientific attitudes among students. Collaborative programs, such as joint science education initiatives and vocational training partnerships, provide opportunities for Thai and Chinese students to engage in cross-cultural scientific inquiry and innovation which would help develop scientific attitudes [14, 15]. Furthermore, institutional collaborations—such as those between the Thailand Institute of Scientific and Technological Research (TISTR) and Chinese universities—enhance teacher capacity, curriculum quality, and research environments that support students' engagement with science [15]. Therefore, research on Thai and Chinese students' scientific attitudes is important for understanding how to nurturing future scientists and innovators within this cooperative framework.

Culture influences scientific attitudes by shaping values, educational practices, and behavioral patterns [17, 18]. Both China and Thailand are developing countries in Asia that prioritize science education at the basic education level. China's Compulsory Education Science Curriculum Standards (2025 Edition) [12] and Thailand's science learning standards framework based on the 2008 Basic Education Core Curriculum (B.E. 2551) [13] both explicitly include "cultivation of scientific attitudes" as a goal. However, there are significant differences in the cultural traditions of the two countries (e.g., perceptions of authority, views of nature). Differences exist in religion and values between Thai Buddhist culture (emphasizing collectivism, altruism) and Chinese Confucian culture (emphasizing responsibility and achievement) [19]. Thai culture places greater emphasis on cooperation and emotional interaction, while China emphasizes authority and collectivism more [42]. Thailand places more emphasis on practical operation, while China may focus more on theoretical knowledge transmission [42]. Thailand's hierarchical social structure and "krengjai" culture (respect/consideration for others to maintain harmony) influence students to tend to respect teachers and avoid open questioning [18]. Science education in China is influenced by Confucian culture and exam-oriented culture, emphasizing knowledge accuracy and rigor. China also has a culture of respect for teachers and "face," but intense competition for higher education sometimes leads students to respond to external evaluation through compliance or high levels of engagement [19].

The role of cultural factors in shaping scientific attitudes is emphasized in both theoretical and empirical research: science education should pay attention to cultural border crossing and teaching strategies relevant to local contexts [16, 17]. Students are increasingly influenced by their cultural backgrounds, facilitating the analysis of how cultural factors shape scientific attitudes. Existing literature includes comparisons of scientific literacy or attitudes between Thailand and Indonesia [26], and comparisons between Finland and Thailand regarding differences in scientific literacy dimensions [25], but none involve China. While some studies explore the scientific attitudes of Thai primary and secondary students [30, 43-45], research on scientific attitudes in China mostly focuses on Grade 7-9 students or older groups [27]. Sixth-grade students are at a critical period of cognitive development, where abstract thinking abilities begin to form and scientific attitudes are highly malleable [21, 22]. As the final stage of primary education, the scientific attitudes of sixth-grade students can comprehensively reflect the overall quality of primary science education in both countries [23, 24]. Therefore, studying the differences in scientific attitudes of sixth-grade students is particularly important. This study focuses on Grade 6 elementary students from China and Thailand, using quantitative analysis to reveal differences in scientific attitudes at both the overall level and across various dimensions, thereby reflecting the interaction between educational systems and cultural backgrounds. The study aims to answer the following questions:

What are the differences in scientific attitudes between Chinese and Thai students at the overall level and across dimensions?

The findings will provide empirical evidence for designing cross-cultural science education strategies, helping to cultivate talent capable of addressing global challenges. In today's technology-driven world, understanding and bridging cultural influences on scientific attitudes is critical for building inclusive educational ecosystems for Thailand and China cooperation in developing human resources in science and research.

Materials and Methods

This study compared scientific attitudes among sixth-grade primary school students in China and Thailand using a questionnaire survey method. The research focuses on five core dimensions: curiosity, open-mindedness, critical thinking, collaborative spirit, and rigor.

Participants: The sample included 1,601 sixth-grade students from urban areas in China (A total of 850 questionnaires were distributed, 832 were returned, and 12 invalid questionnaires (response time < 90 seconds, all items selected the same option) were excluded, resulting in 820 valid samples (effective response rate = 96.5%) The sample included 428 boys (52.2%) and 392 girls (47.8%). and Thailand (A total of 810 questionnaires were distributed, 795 were returned, and 14 invalid questionnaires were excluded, resulting in 781 valid samples (effective response rate = 96.4%) The sample included 376 boys (48.1%) and 405 girls (51.9%). Inclusion criteria: Enrolled sixth-grade students aged 11–12 years who volunteered to participate. Exclusion criteria: Students with special educational needs who could not complete the questionnaire independently. The two groups showed no significant difference in age distribution (p > .05), and had similar gender structures, with good comparability.

Ethical Considerations: This study was approved by the Ethics Review Committee of Srinakharinwirot University (Approval No. SWUEC-672670), and all procedures strictly followed the Declaration of Helsinki. Written approval was obtained from the administrative department of each participating school prior to the survey. Informed consent forms were distributed to parents/guardians of all participants, clearly stating the research purpose, anonymity principle, voluntary participation right, and the right to withdraw at any time without adverse consequences. Only students whose parents provided written consent and who themselves agreed to participate were included in the survey. All data were stored in encrypted form and used only for statistical analysis, with strict confidentiality of personal information.

Instruments: Data were collected online and offline. The questionnaire contained 25 items measuring five dimensions using a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) see Table 1. A standard back-translation procedure was adopted to ensure cross-linguistic and cross-cultural equivalence between the Chinese and Thai versions. To ensure that the questionnaire content closely aligns with the research objectives, three scientific experts were invited to assess item-objective congruence using the Item-Objective Congruence Index (IOC). All 25 items in this study achieved an IOC value of 1.00, indicating exceptionally high consistency and validity of the questionnaire content. The scientific attitude questionnaire demonstrated high reliability (Cronbach's α = .95) and structural validity (Kaiser-Meyer-Olkin = .98; Bartlett's test of sphericity, $\chi^2(300)$ = 19,777.29, p < .001). The Cronbach's α coefficients for each dimension were: Curiosity = .82, Openness = .81, Critical Thinking = .83, Collaborative Spirit = .82, Rigor = .84. All dimensions had Cronbach's α coefficients above .80, indicating good internal consistency. Confirmatory Factor Analysis (CFA) was conducted using AMOS 24.0 to verify the five-dimensional structural model. The model fit indices are shown in Table 1, all meeting acceptable standards and indicating good model fit. All item factor loadings ranged from 0.62 to 0.85 (Table 1), all above the critical value of 0.60. The Average Variance Extracted (AVE) of each dimension was greater than 0.50, and Composite Reliability (CR) was greater than 0.70, indicating good convergent validity. Cross-loadings between dimensions were all below 0.30, indicating good discriminant validity. Specifically, Q2 (curiosity dimension) and Q16 (collaborative spirit dimension) had cross-loadings < 0.30, with clear dimensional distinction.

Table 1 Items of scientific attitude questionnaire and factor loadings of items by dimension.

Dimensions		Questions	Factor Loading
Curiosity	Q1	I'm excited to learn new scientific knowledge.	0.72
	Q2	I love doing scientific inquiry such as exploration experiments.	0.75
	Q3	I often ask my teachers questions about the natural world.	0.68
	Q4	I love reading books and magazines about science and/or use internet for searching for science.	0.70
	Q5	I'm willing to take the time to explore scientific phenomena that I don't understand.	0.73
Openness	Q6	I am open to new scientific discoveries, even if they challenge my beliefs.	0.69
	Q7	I think that openness is important to learning new scientific concepts.	0.67
	Q8	I am willing to change my opinion based on new evidence.	0.74
	Q9	I enjoy discussing scientific issues with friends or people who hold different points of view.	0.71
	Q10	I am willing to consider scientific knowledge that differ from my current views.	0.72
Critical Thinking	Q11	I always check the sources of scientific information to assess their reliability.	0.73
	Q12	I consider the quality and relevance of the evidence when evaluating scientific information.	0.75
	Q13	I often question scientific knowledge to ensure they are based on sufficient evidence.	0.70
	Q14	I am willing to look at scientific issues from multiple perspectives.	0.72
	Q15	I think it's important to avoid bias in scientific inquiry.	0.76

Table 1 Items of scientific attitude questionnaire and factor loadings of items by dimension. *(cont.)*

Dimensions		Questions	Factor Loading
Collaborative Spirit	Q16	I enjoy doing scientific inquiry with my classmates.	0.71
	Q17	I would like to share my scientific findings with my classmates.	0.73
	Q18	I think teamwork is important to solve scientific problems.	0.76
	Q19	I am willing to take on different roles in scientific inquiry such as exploration experiments to support team goals.	0.74
	Q20	I believe that by working together, we can better understand scientific concepts.	0.72
Rigor	Q21	I think it's very important to record data accurately in scientific inquiry such as exploration experiments.	0.78
	Q22	I am willing to use control variables in the experiment to ensure the accuracy of the results.	0.80
	Q23	I believe that rigor in data analysis is the key to drawing reliable conclusions.	0.85
	Q24	I am willing to take the time to ensure that my scientific reports are accurate.	0.76
	Q25	I think it is necessary to repeat the experiment in scientific inquiry to verify the results.	0.79

Data were collected through a combination of online and offline methods.

Chinese sample: Online questionnaires were distributed via the Wenjuanxing platform. With the cooperation of head teachers, students completed the questionnaire independently during class time. Research assistants provided online guidance for any questions about item comprehension.

Thai sample: Paper questionnaires were used. Trained research assistants distributed the questionnaires in class, explained the instructions and precautions uniformly, and students completed them independently. Questionnaires were collected on site after completion.

Data Analysis: To analyze students' scientific attitude scores, the total questionnaire score of each participant was calculated. The scientific attitude questionnaire consists of 25 items, each scored on a 5-point Likert Scale (1 = Strongly Disagree, 5 = Strongly Agree), resulting in a theoretical total score range of 25 (minimum) to 125 (maximum). The threshold of 100 for the High level is set at 80% of the full score (125×80% = 100), a widely accepted benchmark in educational assessment for identifying excellent performance in attitudinal or competency measurements. The Average level (70 – 99) covers the core score range of the sample, and the Low level (below 69) represents a score of less than 56% of the full score, indicating a low overall recognition of scientific attitude dimensions among students. Thus, the students were classified into three levels as shown in Table 2.

Normality of total scores and dimensional scores was tested using the Kolmogorov-Smirnov test and Shapiro-Wilk test. Results showed that all variables had $p < .001$, rejecting the null hypothesis of normal distribution. Although the sample size is large, the data showed a degree of negative skewness. The non-parametric

Mann-Whitney *U* test, which is based on rank order and unaffected by distribution shape, is more robust and can effectively reduce the risk of Type I error. Therefore, differences were compared using means, standard deviations, and the Mann-Whitney *U* test. The effect size was calculated using the formula $r = \frac{|Z|}{\sqrt{N}}$, where z is the standardized test statistic (z-value), and N is the total sample size (sum of the two group sample sizes). This approach was used to analyze the data. In interpreting effect size here Muijs [46] gives the following guidance: 0.00 - 0.10 (weak effect); 0.10 - 0.30 (modest effect); 0.30 - 0.50 (moderate effect); > 0.50 (strong effect).

Table 2 Classification criteria for total scientific attitude scores.

Score Range	Level	Description
100 or above	High	The student demonstrates a strong and positive scientific attitude across all five dimensions.
Between 70 - 99	Average	The student shows a moderate level of scientific attitude with room for improvement.
Below 69	Low	The student exhibits a weak scientific attitude and may require targeted intervention.

Results

Overall Differences in Scientific Attitudes Between Chinese and Thai Students

There are 820 6th Grade Chinese students and 781 6th Grade Thai students responded to the same questionnaire. For the mean score of total scientific attitudes scores compared between Chinese and Thai students are shown as in the Table 3. Chinese students demonstrated higher mean total score in scientific attitudes than Thai students (China: M = 92.67, SD = 17.77; Thailand: M = 90.42, SD = 18.41). The Mann-Whitney *U* test indicated a statistically significant difference in total scientific attitude scores between Chinese and Thai students (U = 297365.00, z = -2.47, $p < .05$). However, the effect size was small (r = .06), suggesting that although the difference reached statistical significance, indicating that the practical magnitude of the overall difference was limited shown in Table 3.

Table 3 Difference between scientific attitude of sixth grade students in China and Thailand for the total sample. (N = 1,601)

Panel A: Descriptive Statistics for Total Score			
	n	*M*	*SD*
Nationality: China	820	92.67	17.77
Nationality: Thailand	781	90.42	18.41
Panel B: Mann-Whitney *U* Test Statistics			
Mann-Whitney *U*		297,365.00	
Standardized Test Statistic (z)		-2.47	
Asymptotic Sig. (2-tailed)		0.01	

The distribution of attitude levels is shown in Figure 1. The proportion of students at the high level was higher in China (38.50%) than in Thailand (31.80%), while the proportions of average and low levels were slightly lower in China as shown in Figure 1.

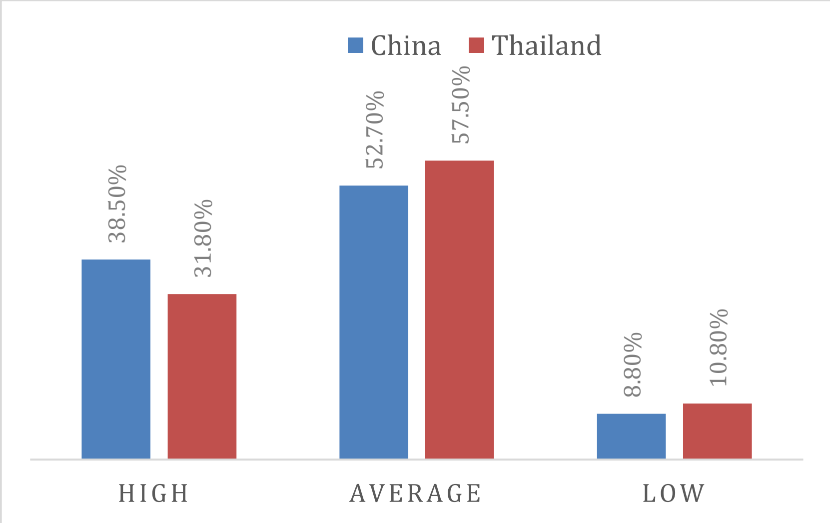

Figure 1 Percentage distribution of scientific attitude levels in Chinese and Thai students.

Differences Across Scientific Attitude Dimensions

Curiosity: There was no statistically significant difference in the curiosity dimension between the two groups, U = 314,774.50, z = -0.59, p = .555. Mean scores were very close: China M = 3.55, Thailand M = 3.53 (Table 4).

At the item level (Table 5): Chinese students scored significantly higher on Q2 (preference for inquiry-based practice; U =292,240.50, z = 6.63, p = .001, r = .17) and Q4 (preference for reading and searching scientific information; U =275,597.00, z = -4.50, p < .001, r = .12). Thai students scored significantly higher on Q3 (frequency of asking teachers questions about nature; U =364,608.00, z = 5.06, p < .001, r = .13). No significant differences were found in Q1 (excitement about learning new scientific knowledge) and Q5 (willingness to spend time exploring unfamiliar phenomena).

Table 4 Descriptive statistics and Mann-Whitney U test results for curiosity by nationality.

Nationality	n	M	SD	U	z	p
China	820	3.55	0.82	314,774.50	-0.59	.555
Thailand	781	3.53	0.77			

Table 5 Descriptive statistics and Mann-Whitney *U* test results for curiosity items by nationality.

Curiosity	China		Thailand		Mann-Whitney *U* Test		
Questions Item	*M*	*SD*	*M*	*SD*	*U*	*z*	*p*
Q1	3.85	1.07	3.84	0.93	312,876.50	-0.83	.405
Q2	3.99	1.06	3.87	0.99	292,240.50	6.63	.001
Q3	2.87	1.14	3.14	0.97	364,608.00	5.06	< .001
Q4	3.50	1.18	3.24	1.07	275,597.00	-4.50	< .001
Q5	3.53	1.17	3.56	1.03	321,126.00	0.10	.918

Openness: There was a statistically significant difference in the openness dimension between the two groups, $U = 297{,}374.50$, $z = -2.48$, $p = .013$. Chinese students had a higher mean score ($M = 3.72$) than Thai students ($M = 3.64$), with a weak effect size ($r = .06$; Table 6).

At the item level (Table 7): Chinese students scored significantly higher on Q8 (willingness to revise views based on evidence; $U = 283{,}860.00$, $z = -4.11$, $p < .001$, $r = .10$) and Q9 (enjoyment of discussing scientific issues with people holding different views; $U = 287{,}832.00$, $z = -3.65$, $p < .001$, $r = .09$). No significant differences were found in Q6 (openness to new discoveries challenging personal beliefs), Q7 (recognition of the importance of openness), and Q10 (willingness to consider different scientific views).

Table 6 Descriptive statistics and Mann-Whitney *U* test results for openness by nationality.

Nationality	*n*	*M*	*SD*	*U*	*z*	*p*
China	820	3.72	0.84	297,374.50	-2.48	.013
Thailand	781	3.64	0.83			

Table 7 Descriptive statistics and Mann-Whitney *U* test results for openness items by nationality.

Openness	China		Thailand		Mann-Whitney *U* Test		
Questions Item	*M*	*SD*	*M*	*SD*	*U*	*z*	*p*
Q6	3.61	1.12	3.54	1.03	306,326.00	-1.57	.118
Q7	3.88	1.09	3.86	1.02	313,937.00	-0.71	.477
Q8	3.85	1.09	3.67	1.04	283,860.00	-4.11	< .001
Q9	3.63	1.15	3.48	1.04	287,832.00	-3.65	< .001
Q10	3.64	1.12	3.65	1.47	311,324.00	-1.00	.316

Critical Thinking: There was no statistically significant difference in the overall critical thinking dimension between the two groups, $U = 331{,}339.50$, $z = 1.21$, $p = .227$. Mean scores were similar: China $M = 3.52$, Thailand $M = 3.56$ (Table 8).

At the item level (Table 9): Thai students scored significantly higher on Q13 (actively questioning scientific knowledge to ensure evidence basis; $U = 379{,}499.50$, $z = 6.63$, $p < .001$, $r = .17$). Chinese students scored significantly higher on Q15 (recognition of the importance of avoiding bias in inquiry; $U = 286{,}979.50$,

z = -3.74, p < .001, r = .09). No significant differences were found in Q11 (checking information sources), Q12 (evaluating evidence quality), and Q14 (viewing issues from multiple perspectives).

Table 8 Descriptive statistics and Mann-Whitney *U* test results for critical thinking by nationality.

Nationality	*n*	*M*	*SD*	*U*	*z*	*p*
China	820	3.52	0.82	331,339.50	1.21	.227
Thailand	781	3.56	0.80			

Table 9 Descriptive statistics and Mann-Whitney *U* test results for critical thinking items by nationality.

Critical Thinking	C hina		Thailand		Mann-Whitney *U* Test		
Questions Item	***M***	***SD***	***M***	***SD***	***U***	***z***	***p***
Q11	3.51	1.13	3.54	1.01	320,872.50	0.08	.940
Q12	3.59	1.11	3.54	0.97	307,104.50	-1.48	.139
Q13	3.13	1.25	3.53	1.02	379,499.50	6.63	< .001
Q14	3.69	1.14	3.69	1.04	315,876.50	-0.49	.625
Q15	3.69	1.13	3.51	1.06	286,979.50	-3.74	< .001

Collaborative Spirit: There was a statistically significant difference in the collaborative spirit dimension between the two groups, U = 288,156.50, z = -3.48, p = .001. Chinese students scored higher (M = 3.85) than Thai students (M = 3.72), with a weak effect size (r = .06; Table 10).

At the item level (Table 11): Chinese students scored significantly higher on Q17 (willingness to share scientific findings; U = 294,730.00, z = -2.87, p = .004), Q18 (recognition of the importance of teamwork; U = 285,563.50, z = -3.93, p < .001), Q19 (willingness to adjust roles for team goals; U = 276,684.00, z = -4.91, p < .001), and Q20 (belief that teamwork improves understanding; U = 285,416.50, z = -3.94, p < .001). No significant difference was found in Q16 (enjoyment of doing inquiry with classmates; p = .983).

Table 10 Descriptive statistics and Mann-Whitney *U* test results for collaborative spirit by nationality.

Nationality	*n*	*M*	*SD*	*U*	*z*	*p*
China	820	3.85	0.89	288,156.50	-3.48	.001
Thailand	781	3.72	0.86			

Table 11 Descriptive statistics and Mann-Whitney *U* test results for collaborative spirit items by nationality.

Collaborative Spirit	China		Thailand		Mann-Whitney *U* Test		
Questions Item	***M***	***SD***	***M***	***SD***	***U***	***z***	***p***
Q16	3.75	1.17	3.78	1.08	320,018.00	-0.02	.983
Q17	3.73	1.16	3.61	1.06	294,730.00	-2.87	.004
Q18	3.98	1.09	3.80	1.07	285,563.50	-3.93	< .001
Q19	3.84	1.12	3.62	1.03	276,684.00	-4.91	< .001
Q20	3.94	1.08	3.75	1.09	285,416.50	-3.94	< .001

Rigor: There was a highly significant difference in the rigor dimension between the two groups, U = 263,362.00, z = -6.17, p < .001. Chinese students scored substantially higher (M = 3.89) than Thai students (M = 3.64), with a mean difference of 0.25 and a modest effect size (r = 0.15; Table 12).

At the item level (Table 13), Chinese students scored significantly higher on all five items, with the largest difference in Q23 (recognition of the importance of rigorous data analysis for reliable conclusions).

Table 12 Descriptive statistics and Mann-Whitney *U* test results for rigor by nationality.

Nationality	*n*	*M*	*SD*	*U*	*z*	*p*
China	820	3.89	0.82	263,362.00	-6.17	< .001
Thailand	781	3.64	0.83			

Table 13 Descriptive statistics and Mann-Whitney *U* test results for rigor items by nationality.

Rigor	China		Thailand		Mann-Whitney *U* Test		
Questions Item	*M*	*SD*	*M*	*SD*	*U*	*z*	*p*
Q21	4.03	1.05	3.79	1.02	272,363.50	-5.44	< .001
Q22	3.86	1.05	3.57	1.01	265,660.00	-6.17	< .001
Q23	3.94	1.07	3.52	1.07	244,840.00	-8.49	< .001
Q24	3.68	1.08	3.54	1.02	292,685.50	-3.11	.002
Q25	3.95	1.08	3.77	1.10	289,354.50	-3.49	< .001

Discussion

Overall Characteristics of Scientific Attitudes

The results showed that sixth-grade students in both China and Thailand had moderately positive scientific attitudes overall, with most students at the average level and about one-third at the high level. Chinese students had a significantly higher total score, but the effect size was very small, indicating limited practical significance of the overall difference. This pattern is consistent with Bybee [32], who noted that primary school students in different cultural contexts generally show positive attitudes toward science, and cross-cultural differences at the overall level are usually small.

The small overall difference may be explained by two factors. First, both countries attach importance to primary science education and take scientific attitude cultivation as a core curriculum objective, leading to similar overall performance. Second, sixth-grade students are in the early stage of scientific attitude formation, and curiosity and interest in science are universal developmental characteristics at this age, which are less affected by cultural differences [47].

Dimensional Differences and Potential Mechanisms

Curiosity: No Overall Difference, Divergent Item-Level Performance

The absence of a significant difference in overall curiosity aligns with the view that epistemic curiosity is a universal psychological trait in childhood [48]. At the item level, however, the two groups showed distinct characteristics. Chinese students performed better in structured inquiry activities and independent knowledge acquisition, while Thai students were more inclined to actively ask teachers questions. This difference may be related to different classroom teaching modes. Chinese primary science education has widely promoted inquiry-based teaching in recent curriculum reforms, with standardized experimental inquiry activities in classrooms, so students are more familiar with and prefer structured inquiry [49]. In addition, Chinese students have richer access to extracurricular science reading materials and online learning resources, which improves their performance in independent knowledge acquisition. Thai classrooms, on the other hand, have a more supportive atmosphere, and students are more willing to ask teachers questions based on daily life phenomena [50]. However, this explanation is speculative and needs to be verified by classroom observation studies in the future.

Openness: Slightly Higher Performance Among Chinese Students

Chinese students scored significantly higher in openness, especially in willingness to revise views based on evidence and enjoyment of discussing diverse perspectives. This may be related to recent core literacy reforms in Chinese science education, which emphasize argumentation-based inquiry and encourage students to express different views and conduct evidence-based debates in classrooms [51]. Although Thai culture advocates harmony and free expression, the traditional kreng jai cultural norm emphasizes respect for authority and maintenance of interpersonal harmony, which may reduce students' willingness to directly express different views or challenge others' opinions in formal academic discussions [18]. This may explain why Thai students' recognition of the importance of openness did not differ significantly from Chinese students, but their actual behavioral tendency to express different views was relatively weaker. It should be noted that the effect size of this difference is small, and the cultural influence should not be overgeneralized.

Critical Thinking: No Overall Difference, Complementary Item Characteristics

The absence of a significant difference in overall critical thinking suggests that both groups have similar levels of critical thinking development at this age, but with different strengths. Thai students were more inclined to actively question existing knowledge, while Chinese students paid more attention to avoiding bias in inquiry. This pattern may be related to different teaching orientations. Chinese science education emphasizes the standardization of experimental procedures and rigor of reasoning, and students are trained to pay attention to avoiding errors and bias in inquiry, leading to higher recognition of the importance of bias avoidance [52]. However, influenced by exam-oriented culture and respect for authority, students are relatively less inclined to actively question textbook knowledge or authoritative conclusions. Thai primary science education, on the other hand, pays more attention to students' free exploration and encourages questioning, but provides relatively less training in systematic evidence evaluation and bias control [50]. This finding suggests that critical thinking cultivation in the two countries has complementary strengths. China can learn from Thailand's experience in encouraging active questioning, while Thailand can draw on China's experience in cultivating rigorous evidence evaluation and bias awareness.

Collaborative Spirit: Higher Task-Oriented Cooperation Awareness Among Chinese Students

Chinese students scored significantly higher in collaborative spirit, especially in recognition of teamwork importance, willingness to share findings, and role adjustment for team goals. This may be related to China's stronger collectivist cultural orientation, and group work in classrooms usually has clear task division and efficiency orientation, leading to stronger task-oriented cooperative awareness among students [53]. Thai students also had a positive attitude toward cooperative learning, and they enjoyed the relaxed atmosphere of group activities (as shown by the non-significant difference in Q16). However, Thai students are relatively less task-oriented in cooperative learning, and pay more attention to interpersonal harmony in the process of cooperation rather than task completion efficiency [54], leading to slightly lower scores on items related to task effectiveness.

Rigor: Largest Dimensional Difference, Obvious Advantage for Chinese Students

The rigor dimension showed the largest difference among all dimensions, with a modest effect size. This result is consistent with the notion that East Asian students influenced by exam-oriented culture usually perform better in learning rigor and accuracy [55]. This difference may be mainly attributed to different educational environments. Chinese basic education has always emphasized accuracy and standardization. In science education, students are required to record experimental data accurately, strictly control variables, and repeatedly verify results. Exam-oriented evaluation also strengthens students' attention to accuracy and rigor [56]. Thai education, on the other hand, pays more attention to the inquiry process and students' interest experience, and has relatively lower requirements for operational standardization and data recording accuracy, leading to relatively weaker rigor awareness among students [57]. It should be emphasized that this difference does not imply that one educational model is superior to the other. Excessive emphasis on rigor may limit students' creative exploration, while excessive emphasis on interest may lead to non-standard scientific practice. The ideal model should balance interest cultivation and rigor training.

Conclusions

This study compared the scientific attitudes of sixth-grade primary school students in urban areas of China and Thailand, and drew the following main conclusions.

At the overall level, students in both countries had moderately positive scientific attitudes. Chinese students had a significantly higher total score than Thai students, but the effect size was very small, with limited practical magnitude of difference.

At the dimensional level, there was no significant difference in overall curiosity, but item-level differences existed. Chinese students performed better in structured inquiry and independent knowledge acquisition, while Thai students were more inclined to actively ask teachers questions. Chinese students scored significantly higher in openness, mainly reflected in stronger willingness to revise views based on evidence and participate in perspective discussions. There was no significant difference in overall critical thinking, with complementary item-level characteristics. Thai students were more inclined to active questioning, while Chinese students paid more attention to bias avoidance. Chinese students scored significantly higher in collaborative spirit, with stronger task-oriented cooperative awareness. The rigor dimension showed the largest difference, with Chinese students having a significant advantage and a modest effect size.

The differences in scientific attitudes between the two groups may be related to different cultural traditions and educational models. The two countries have respective strengths in cultivating scientific attitudes, and can achieve complementary advantages through cross-cultural educational cooperation.

Future Chinese-Thai science education cooperation should integrate the advantages of the two educational models, balance the cultivation of curiosity, openness, critical thinking, collaborative spirit and rigor, and comprehensively improve students' scientific literacy, so as to lay a foundation for training future scientific and technological innovative talents and promoting global scientific cooperation.

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