

Enhancing Scientific Argumentation Skills in the Classroom: Strategies for Fostering Critical Thinking in Science Education

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Recibido / Received: 04/03/2025
Aceptado / Accepted: 19/05/2025

Abstract: Scientific argumentation is an essential feature of science learning because it prepares students to make arguments based on evidence that helps them to argue critically. This article was based on a study that sought to ascertain the implications of incorporating socio-scientific issues (SSI), organised peer discussion tasks and explicit instruction on critical thinking of scientific argumentation of upper primary school in China. A questionnaire survey was used, and a quantitative cross-sectional research design was carried out, where 100 students were surveyed. The results revealed that all three strategies used strongly predicted the ability of argumentation, with the most significant effect coming in the SSI Integration and then closely followed by the structured peer discussion and explicit instruction. This research study reveals that the combined model is the best way of encouraging scientific argumentation. It suggests the combination of SSI and organised discussions and a famous bone-up instruction. In practice, this can lend itself to lesson planning so that content and reasoning skills are considered equal. Limitations: One is the absence of causality, two is non-self-reporting, and three is an inadequate sample size.

Keywords: Scientific Argumentation, Socio-Scientific Issues, Peer Discussion, Critical Thinking, Science Education.

1. Introduction

Scientific argumentation is becoming an important part of science teaching, which allows students to create, evaluate, and justify their assertions by employing evidence and rational support. These skills do not just increase conceptual understanding in upper primary classrooms but create critical thinking dispositions that are essential to lifelong learning (Vaghela & Parsana, 2024). In the Chinese learning environment, increasing emphasis is being placed on aligning classroom experiences with inquiry-oriented and student-centred learning approaches aimed at fostering higher-order thinking (Fulmer, Ma & Liang, 2019). These developments have been reinforced by curriculum reforms and research initiatives aimed at accelerating the preparation of young scholars to engage with complex, real-world issues scientifically.

More recent literature focuses on the need to develop scientific argumentation as one of the 21st-century skills in science. The process of scientific argumentation not only enhances content knowledge but also develops evidence assessment, the identification of alternative explanations, and productive dialogue in a mutually respectful way (Okan & Kaya, 2023). The new curriculum of reformed science introduced in China facilitates student engagement, inquiry-driven learning, and links to the real world, thus ensuring that scientifically literate citizens are prepared to solve complex problems in society. Socio-scientific issues (SSIs) also turned out to be a very productive method of placing argumentation in a real context since students who engage in them are encouraged to reason about a controversial topic on the verge of evidence, moral and social implications (Fang, Hsu & Lin, 2019). In the same sense, informed discussion among peers has been found to leave room to promote the refinement of debates, the undermining of assumptions, and the enrichment of understanding as a result of informed interaction (Yuanzheng & Chinokul, 2023). Teaching critical thinking strategies by having the students learning claim-evidence-reasoning (CER) frameworks equips students with mental tools to track their arguments and assess them methodologically (Luo et al., 2023). These strategies, as a combination, have the potential to enhance argumentation competency in Chinese upper primary science classrooms.

1.1. Problem Statement

Although curricular changes have been made, studies in China show that a majority of upper primary science classrooms continue to promote the use of rote learning and motivated teacher delivery in science, and this environment leaves little chance of students engaging in genuine argumentation (Li, 2023). This is further added by a deficiency of special instructional procedures to assist students in improving the ability of critical thinking and reasoning based on evidence (Jiang, 2021). Research has indicated that although Chinese students can do well using factual recall, they have been shown to fail in discerning the validity of evidence, viewing things through more than one angle or facing the development of logical arguments (Tian et al., 2025). Moreover, SSI integration is performed inadequately, and facilitation may be happening in an unstructured way, limiting its ability to provoke constructive discussions (Ngo et al., 2023). In the absence of purposeful application of structured peer conversations, the students are likely to engage in superficial interactions instead of keen reasoning (Giri & Paily, 2020). Likewise, teaching on critical thinking strategies has been irregular, and many students lack a proper guide on how to build important arguments or how to refute them as well (Su et al., 2025). The performance of science education in China needs to address these gaps to achieve its vision set to producing scientifically literate and critical thinkers who can contribute to decision-making in society.

1.2. Aims and Objectives

The study aims to understand the best ways to integrate the learning of scientific argumentation in upper primary school children, with the example of China, where the influences of three various approaches to instruction, such as the incorporation of socio-scientific issues, implementation of structured peer discussions, and direct teaching on the methods of critical thinking, were explored. Specifically, the objectives are:

- To determine the effect of integrating socio-scientific issues into science lessons on the scientific argumentation ability of upper primary school students.
- To examine the impact of structured peer discussion activities on the scientific argumentation ability of upper primary school students.
- To assess the influence of explicit instruction in critical thinking strategies on the scientific argumentation ability of upper primary school students.

1.3. Significance of Study

Educators, curriculum designers and policymakers in China and beyond find significance in this study. Its approach of examination through empirical investigation on the success of various instructional strategies in terms of scientific argumentation skills development gives it an evidence-based recommendation concerning improving the science pedagogy at the primary school level. The discoveries can inform teachers about creating lessons that no longer rely on rote-based content delivery and create high analysis, collaborative dialogue, and exposure to real-world problems. Moreover, the combination of SSI with structured peer discussion and overt instruction in critical thinking is in step with the international demands to provide students with competencies that are required to live in knowledge-based societies that are democracies. When viewed in the backdrop of ongoing education reforms initiated by the Chinese government, the given research provides viable means by which to operationalise curricular objectives and hence, promote the production of critical, notable scientists that are scientifically literate and equipped to meet the challenges of the future.

2. Literature Review

The body of work in the science education literature highlights the importance of developing teaching strategies that would actively help to develop skills in scientific argumentation in students. Recent research indicates such skills are not naturally occurring but must be cultivated by deliberate pedagogical action, pushing students to argue and reason using evidence, assess competing claims and be transparent cognitive actors (Mang et al., 2021). These skills are imperative in the upper primary science educational context of China, to achieve both goals, supporting conceptual mastery and higher-order thinking skills development. The given literature review consists of the synthesis of the current studies on the three methods of instruction, namely integrating socio-scientific problems, using effects of structured peer discussions, and providing explicit teaching in critical thinking strategies, along with their placement into a meaningful theoretical framework.

2.1. Integration of Socio-scientific Issues and Scientific Argumentation Ability

2.1.1. Role of Socio-scientific Issues in Science Education

Socio-scientific issues (SSIs) have been listed among highly productive pedagogical working strategies used to enhance engagement of students and encourage critical thinking in the science learning environments (Wen et al., 2024). They introduce a real-life issue (climate change or genetic engineering) that is a complex phenomenon that tends to be controversial in nature and makes students analyse evidence, judge

about ethical ramifications and reflect on other positions (Schabas, 2023). Placing the argumentation into the real-life setting, SSIs help students to understand the importance of science in their lives (Mang et al., 2021). The reason it would work in the Chinese classrooms is that it fits the use of inquiry and problem-solving that is part of the national curriculum, and it creates an opening to leave the rote memorisation behind (Rundgren & Chang Rundgren, 2024). The studies have been demonstrating the idea that SSI-oriented tasks lead to better epistemic comprehension and encourage students to be more involved in scientific practices (Gül & Akcay, 2020).

2.1.2. Empirical Evidence Linking SSI to Argumentation Skills

It has been repeatedly proven by empirical research that SSI-based teaching has a positive impact on the scientific argumentation ability of students. To take a specific instance, Anwar and Ali (2020) discovered that students in the upper primary grades who participated in structured SSI debates made large and significant improvements on the quality of claims, the use of evidence, and integration of counterarguments. Equally, according to one of the studies conducted by Ben-Horin, Kali and Tal (2023), the SSI context helps students transition between descriptive explanations and evidence-based ones of science tasks. A quasi-experimental study conducted by Nugroho et al. (2025) showed that SSI integration is an outstanding intervention to enhance students' ability to criticise faulty logics, especially when this integration is scaffolded by providing explicit arguments. Adoption of SSIs that are culture-friendly has been observed to increase the amount and the complexity of arguments produced by the students (e.g., local environmental issues in the context of Chinese schooling) (Zhu & He, 2022). The evidence indicates the fact that SSI integration is not only a kind of motivational tactic but a material way to the development of a higher level of reasoning.

2.2. Structured Peer Discussion Activities and Scientific Argumentation Ability

2.2.1. Importance of Peer Interaction in Science Learning

The core mechanism of social constructivist approaches is peer discussion, through which knowledge is co-constructed via dialogue and negotiation. Structured peer discussion in the classrooms enables students to explain their thinking, respond to challenges, and improve their thinking based on the intervention provided by their peers in science classes (France, 2021). In an unstructured manner, the conversation can easily dissolve into off-topic or shallow conversations and carefully created plans like assigning individuals roles, using discussion prompts or employing evidence-based reasoning checklists provide deeper cognitive discussion value (Gillies, 2019). Group discussions among peers are a possible way to achieve a balance between control and independence in the Chinese education system of primary schools, where teaching continues to be teacher-centred in its methods (Rapanta et al., 2021).

2.2.2. Effects of Structured Discussion on Argumentation Quality

It has been found that structured discussions with peers are positively correlated with the improvement of the ability of argumentation based on empirical research. McFadden and Roehrig (2019) found that primary students involved in directed peer

discussion showed greater evidence use and explicitness of reasoning patterns than students who engaged in informal talk. According to a mixed-methods study by Wei et al. (2021), structured group work decreased the tendency of the students to establish arguments and defend their claims. Moreover, according to the research made by Liu et al. (2025), structured peer discussion also proved to be useful in increasing the meta-cognitive awareness of the argumentation process, which resulted in more intentional and consistent reasoning. These findings correlate with the opinion that dialogue, scaffolded, can be used as a constructive arena for both argument construction and assessment.

2.3. Explicit Instruction in Critical Thinking Strategies and Scientific Argumentation Ability

2.3.1. Teaching Critical Thinking in Primary Science

The reasoning of science is also based on Critical thinking methods such as identifying assumptions, evidence evaluation and logical inference. Explicit didactics of such skills represent aligning the thought process with such students and equipping them with concrete structures, including the claim-evidence-reasoning (CER) model, to name a few, to frame their reasoning (Izquierdo-Acebes & Taber, 2024). The feasibility of turning critical thinking into a stated outcome should be understood in the Chinese context, in which direct instruction is common. The students have a proven way to address and formulate scientific statements through cognitive tool building (Xie, Smith & Davies, 2025). Such a method supplements an education of content so that students can come to grips with the intricacies of scientific argument.

2.3.2. Research Evidence on Explicit Critical Thinking Instruction

Investigations in primary science classrooms always record positive results on the explicit instruction of critical thinking. As noted by Khishfe (2021), systematic CER-based teaching resulted in higher coherence in argued statements and the precision of the applied scientific words. In yet another research, Skoumios (2023) discovered that when students were taught to analyse the credibility of sources and validity of evidence, there was a significant enhancement in written and oral arguments. On the same note, Chen and Kalyuga (2020) have observed that explicit reasoning instruction assisted students in making the shift from reliance on intuitive judgment to the usage of analytical judgment to solve science-related problems. These results support the argument that explicit critical thinking instruction is not only effective, but must be provided in a long-lasting way in order to show significant increases in the argumentation capability.

2.4. Theoretical Framework: Argumentation Theory in Science Education

This study is grounded in Toulmin's Argument Pattern (TAP) framework, which conceptualises argumentation as the articulation of a claim supported by evidence and linked through reasoning, with potential rebuttals and qualifiers. Modern-day uses of TAP in the science education context focus on aligning with the argumentative aspects of making components visible to the students, positively altering their reasoning structures and quality. Integrating TAP and synchronising some devices (e.g., SSI integration,

guided peer discussion, and direct instruction in critical thinking) may help teachers to offer students a general and transferable example of argument construction and evaluation. TAP assessment can also be justified in terms of this theoretical framing, as it gives specific guidelines to evaluate the level of the sophistication of student arguments under different contexts.

2.5. Literature Gap

As the research proves the efficiency of SSI integration, intensive peer discussions, and direct guidance of critical thinking, there are still some gaps. The first reason is that very few studies have been done that have investigated these strategies simultaneously in the same learning environment, especially in the Chinese upper primary sphere. Existing studies analyse the two methods individually; hence, there are questions regarding their relative and combined influence on argumentation development. Second, despite the evidence base at the secondary and university level, there is still not enough empirical evidence of SSI-based interventions at the primary level and especially on culturally localised topics of SSI in China. Third, there has been the exploration of structured peer discussions that are mainly carried out in high-achieving schools or urban schools and rarely in various classroom settings. Finally, the overall concept of explicit critical thinking instruction does not necessarily translate to a consistent implementation in Chinese primary science classrooms, resulting in a lack of consistency. The gaps in this area would permit a greater insight into the way scientific argumentation skills can be instilled in young learners.

3. Research Methodology

A well-developed research method allows trust in the findings obtained and experiencing their application in the desired educational environment. In this chapter, the author describes the methodological strategy employed in the study to solve the problem of determining the impact of three strategies of providing instructions to improve the scientific argumentation skill of upper primary school children in China, integrating socio-scientific issues, structured peer discussions and explicit critical thinking instruction. The methodology includes research design, methods of collecting data, sample size, reliability and the procedure of data analysis, and ethical issues.

3.1. Research Method and Design

This study adopts a primary quantitative research method using a questionnaire survey as the main data collection tool. The quantitative approach is suitable to quantify the relationships between these independent variables (SSI integration, structured peer discussion, explicit critical thinking instruction) and the dependent variable (scientific argumentation ability) in a methodical and statistically detectable manner (Chen & Liu, 2023). Research design is non-experimental and cross-sectional, and hence allows ascertaining the data collected in a single instance amongst a predetermined population of upper primary school students. A 5-point Likert scale is designed in the survey tool that was constructed on the existing validated scales and adjusted to the context of the study, where the perceptions and self-reported skills are described. With such design, patterns and correlations between the variables can be identified,

which is appropriate in educational studies where experimentation types of research are not always possible (Fischer, Boone & Neumann, 2023).

3.2. Data Collection Method

The information was gathered by administering printed questionnaires in place of regular science lessons. The instrument would be divided into three parts, namely demographic information, instruments to assess the three independent variables and instruments that assess the dependent variable. The use of surveys was streamlined; teachers managed the process of distribution and collection of surveys, and the process was standardised in all the classrooms that participated in the survey. Data collection in the school context is optimal in ensuring maximum participation and represents the authenticity of the responses given by the students (Yan, Zhang & Dixon, 2022).

3.2.1. Samples and Sample Size

Around 100 upper primary students, composed of children who are in grades 4 to 6 in two Chinese government schools, were the participants. This amount of a sample is sufficient because it complies with the recommendations on regression-based studies, where a minimum of 10 to 15 participants per variable that serves as the predictor should be met (Niu, 2020). A stratified sampling method was also employed whereby the different grades and the genders were represented in the sample in proportion. The inclusion factors are practising science in classes and the permission of both parents and students.

3.2.2. Data Reliability

Cronbach's alpha was used to test reliability, and this was used to calculate internal consistency of the questionnaire. Each subscale had acceptable coefficients equaling 0.70 or more, following suggestions in the literature on educational measurement (Kusmaryono, Wijayanti & Maharani, 2022). Wording was corrected, and the clarity was assessed by holding a pilot study with 15 students who had similar demographics to the main study population.

3.3. Data Analysis Method

Analyses were performed through the SPSS statistical program. The demographic data and key variables were summarised using descriptive statistics (mean, standard deviation and frequencies). A normality test (Shapiro-Wilk) was used to confirm that the data are in conditions of parametric statistics. Pearson correlation was used to gauge the strength and pattern of the relationship that exists between dependent and independent variables. Lastly, the predictive power of each of the instructional strategies on the ability to engage with scientific arguments was identified using a multiple regression analysis where other contributing factors were held constant (Namoun & Alsharqiti, 2021). The combination of such statistical methods enables not only the finding of general patterns but also significant predictors.

3.4. Ethical Consideration

Ethical integrity is central to educational research involving minors. The proposed study was geared toward the permission of the Chinese Ministry of Education and the

criteria of the institutional review board. Informed consent will be obtained from parents or guardians, and assent will be sought from students. The respondents were assured of confidentiality and anonymity, and that the opportunity to participation is voluntary. The dataset was not accompanied by any identifying information, and all collected materials were safely maintained and destroyed at the end of the study. The words being used in the questionnaire were age-appropriate and culturally sensitive, as special care was taken not to make anyone distressed or misunderstood (Huang, Zhou & Sheeran, 2021).

4. Data Analysis

In the chapter, the statistical findings of the study analysing the impacts of combining socio-scientific issues (SSI), structured, peer discussion activities and teaching the strategy of critical thinking on the ability of the students to construct a scientific argumentation are presented. To achieve the research objectives, the various analyses include descriptive statistics, testing reliability, normality, correlation analysis and regression model. Statistical results are interpreted against the background of goals and the nature of the sample used.

4.1. Descriptive Statistics

The demographic data indicates what the sample used in the study consisted of and gives a background against which later results would be deciphered.

Table 1: Frequency of Gender of Respondents.

		Gender			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Boy	54	54.0	54.0	54.0
	Girl	46	46.0	46.0	100.0
	Total	100	100.0	100.0	

As shown in Table 1, the gender distribution was relatively balanced, with 54 boys (54.0%) and 46 girls (46.0%). This near-equal representation reduces the likelihood of gender-related bias in the findings.

Table 2: Frequency of Age of Respondents.

		Age			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	10	18	18.0	18.0	18.0
	11	18	18.0	18.0	36.0
	12	11	11.0	11.0	47.0
	13	22	22.0	22.0	69.0
	14	19	19.0	19.0	88.0
	15	12	12.0	12.0	100.0
	Total	100	100.0	100.0	

Regarding age, Table 2 shows that the participants ranged from 10 to 15 years old, reflecting the target population of upper primary school students. The largest age

group was 13 years old (22.0%), followed by 14 years old (19.0%), and two groups—10 and 11 years old—each representing 18.0% of the sample. Smaller proportions were observed for 12-year-olds (11.0%) and 15-year-olds (12.0%). This distribution indicates a slight skew toward older upper primary students, possibly due to variations in school entry age or grade retention patterns.

Table 3: Frequency of Grades of Respondents.

		Grade			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	4	38	38.0	38.0	38.0
	5	29	29.0	29.0	67.0
	6	33	33.0	33.0	100.0
	Total	100	100.0	100.0	

In terms of grade level, Table 3 reveals that 38.0% of participants were in Grade 4, 29.0% in Grade 5, and 33.0% in Grade 6. The representation across grades is relatively even, ensuring that findings are not disproportionately influenced by a single grade cohort. The diversity in age and grade supports the study's generalizability to upper primary science classrooms.

4.2. Reliability Analysis

The internal consistency of the questionnaire scales was tested with Cronbach's alpha to determine the reliability of the questionnaires.

Table 4: Scale: Integration of Socio-scientific Issues (SSI).

Reliability Statistics	
Cronbach's Alpha	N of Items
.790	5

Table 5: Scale: Structured Peer Discussion Activities.

Reliability Statistics	
Cronbach's Alpha	N of Items
.826	5

Table 6: Scale: Explicit Instruction in Critical Thinking Strategies.

Reliability Statistics	
Cronbach's Alpha	N of Items
.829	5

Table 7: Scale: Scientific Argumentation Ability.

Reliability Statistics	
Cronbach's Alpha	N of Items
.826	5

As shown in Tables 4 to 7, the Integration of Socio-scientific Issues (SSI) scale achieved an alpha of 0.790, exceeding the acceptable threshold of 0.70, indicating satisfactory reliability. The Structured Peer Discussion Activities scale achieved a higher reliability score of 0.826, suggesting strong internal consistency among its five items. The Explicit Instruction in Critical Thinking Strategies scale yielded an alpha of 0.829, also reflecting high reliability. Finally, the Scientific Argumentation Ability scale recorded a Cronbach’s alpha of 0.826, demonstrating strong internal consistency in measuring the dependent variable. These findings establish that the four scales are valid tools for measuring constructs of interest, that is, responses remain the same and can be reproduced using the different items in each scale.

4.3. Normality Analysis

Normality testing was conducted using both the Kolmogorov–Smirnov and Shapiro–Wilk tests, as presented in Table 8 below.

Table 8: Tests of Normality.

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Integration of Socio-scientific Issues (SSI)	.127	100	.000	.933	100	.000
Structured Peer Discussion Activities	.130	100	.000	.938	100	.000
Explicit Instruction in Critical Thinking Strategies	.135	100	.000	.940	100	.000
Scientific Argumentation Ability	.137	100	.000	.933	100	.000
a. Lilliefors Significance Correction						

The results show that all variables, Integration of SSI, Structured Peer Discussion Activities, Explicit Instruction in Critical Thinking Strategies, and Scientific Argumentation Ability, had significance values of 0.000 in both tests, which are below the 0.05 threshold. This indicates that the data significantly deviates from a normal distribution. This was a violation of normality and, therefore, non-parametric statistical methods, which include Spearman’s rho for correlating the relationship of variables, were used in the analysis. Such a decision makes the analysis robust, although the scores are non-normally distributed.

4.4. Correlation Analysis

Spearman’s rho correlations, presented in Table 9 below, reveal strong, positive, and statistically significant relationships between each independent variable and the dependent variable.

Integration of SSI showed the strongest correlation with Scientific Argumentation Ability ($\rho = 0.852, p < 0.01$), suggesting that higher perceptions of SSI integration are strongly associated with higher levels of argumentation ability. Structured Peer Discussion Activities also correlated strongly with Scientific Argumentation Ability ($\rho = 0.838, p < 0.01$), indicating that students who experienced more structured peer discussions tended to report higher argumentation ability. Explicit Instruction in Critical Thinking Strategies showed a slightly lower, though still strong, correlation with Scientific Argumentation Ability ($\rho = 0.770, p < 0.01$). Strong intercorrelations

were also found among the independent variables themselves, particularly between Integration of SSI and Structured Peer Discussion Activities ($\rho = 0.789$, $p < 0.01$), and between Structured Peer Discussion and Explicit Critical Thinking Instruction ($\rho = 0.776$, $p < 0.01$). These relationships suggest that classrooms implementing one of these strategies often incorporate others as part of broader instructional practices.

Table 9: Correlation Coefficients.

Correlations					
			Integration of Socio-scientific Issues (SSI)	Structured Peer Discussion Activities	Explicit Instruction in Critical Thinking Strategies
Spearman's rho	Scientific Argumentation Ability	Correlation Coefficient	.852**	.838**	.770**
		Sig. (2-tailed)	.000	.000	.000
		N	100	100	100

** . Correlation is significant at the 0.01 level (2-tailed).

4.5. Regression Analysis

Table 10: Model Summary.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.897 ^a	.805	.799	.505864604548514

a. Predictors: (Constant), Explicit Instruction in Critical Thinking Strategies, Integration of Socio-scientific Issues (SSI), Structured Peer Discussion Activities

The regression analysis, summarised in Table 10 (Model Summary), shows an overall model R of 0.897, indicating a very high degree of association between the three predictors and Scientific Argumentation Ability. The R^2 value of 0.805 means that approximately 80.5% of the variance in Scientific Argumentation Ability can be explained by the combined influence of Integration of SSI, Structured Peer Discussion Activities, and Explicit Instruction in Critical Thinking Strategies. The adjusted R^2 (0.799) suggests that the model remains robust when accounting for the number of predictors, and the standard error of the estimate (0.506) is relatively small, further supporting model accuracy.

Table 11: Analysis of Variance.

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	101.664	3	33.888	132.427	.000 ^b
	Residual	24.566	96	.256		
	Total	126.230	99			

a. Dependent Variable: Scientific Argumentation Ability
b. Predictors: (Constant), Explicit Instruction in Critical Thinking Strategies, Integration of Socio-scientific Issues (SSI), Structured Peer Discussion Activities

The ANOVA results in Table 11 indicate that the regression model is statistically significant, $F(3, 96) = 132.427$, $p < 0.001$. This confirms that the set of independent variables significantly predicts the dependent variable, aligning with the study's aims.

Table 12: Coefficients of Regression.

Coefficients ^a					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1	(Constant)	.044	.164		.271 .787
	Integration of Socio-scientific Issues (SSI)	.485	.082	.463	5.885 .000
	Structured Peer Discussion Activities	.371	.084	.357	4.431 .000
	Explicit Instruction in Critical Thinking Strategies	.248	.078	.147	2.913 .006

a. Dependent Variable: Scientific Argumentation Ability

Table 12 provides insight into the individual contributions of each predictor. Integration of SSI emerged as the strongest predictor ($B = 0.485$, $\beta = 0.463$, $t = 5.885$, $p < 0.001$), highlighting its substantial impact on Scientific Argumentation Ability. Structured Peer Discussion Activities also had a significant positive effect ($B = 0.371$, $\beta = 0.357$, $t = 4.431$, $p < 0.001$), reinforcing the importance of collaborative discourse in science classrooms. Explicit Instruction in Critical Thinking Strategies, while contributing less than the other two predictors, remained statistically significant ($B = 0.248$, $\beta = 0.147$, $t = 2.913$, $p = 0.006$).

The regression scores suggest that, on the one hand, three strategies are rather effective in improving scientific argumentation as the learning outcome but, on the other hand, SSI integration proves to have the strongest effect and the differences between it and structured peer discussions on the one hand and explicit instruction on critical thinking skills on the other are statistically significant. It is possible that this ranking can be explained by the immersive nature and context-intensive qualities of SSI-based learning, which in essence require the need for argument creation and assessment.

5. Discussion

This chapter explains the findings of the study by linking them to the available literature alongside the three research objectives. The discussion makes the point that each of the instructional strategies, namely the Spectrum of Socio-scientific Issues, Structured Peer Discussion Activities, and Explicit Instruction in Critical Thinking Strategies, is associated with scientific argumentation skill among upper primary students in China.

5.1. Effect of Integrating Socio-scientific Issues on Scientific Argumentation Ability

The findings showed that Integration of Socio-scientific Issues (SSI) exerted the greatest predictive value on scientific argumentation ability, which accounts for a high percentage of the variance in the explaining variable. This evidence is in line with studies which focus on the fact that the context of SSI offers real-life contexts that involve students in the need to construct and justify claims, weigh evidence, and anticipate counterarguments (Anwar & Ali, 2020; Schabas, 2023). Argumentation ability correlates strongly with SSI and supports the argument that SSI is likely to help think critically about the science content and, therefore, to be much more powerful in developing reasoning abilities (Gül & Akcay, 2020; Nugroho et al., 2025). Compared to American ones, the Chinese setting, especially its priority in the curriculum on

inquiry and problem-solving, seems to be a better fit as a counterpart of SSI-based methods, connecting teaching on science to problems in society (Rundgren & Chang Rundgren, 2024; Zhu & He, 2022).

5.2. Effect of Structured Peer Discussion Activities on Scientific Argumentation Ability

The other strong predictor of the ability in scientific argumentation was represented by Structured Peer Discussion Activities, which correlated highly with scientific argumentation. This is consistent with the available literature that states that well-designed peer-to-peer engagement enables students to explain reasoning, critique it, and synthesise different views (France, 2021; Gillies, 2019). This observation confirms the conclusion provided by McFadden and Roehrig (2019) that guided discourse helps produce the use of higher-quality evidence and supports the clarity of the reasoning structure, as opposed to unstructured talk. Also, the meta-cognitive advantages found in the study by Liu et al. (2025) seem to be echoed in the current results, where the structured discussion may have promoted the awareness of the process of argumentation and prompted adults to think wisely. Since many Chinese classrooms are collaborative, particularly at urban primary schools, this is a good complementary strategy to integrate SSI because it offers a social arena to practice argumentation and improve it.

5.3. Effect of Explicit Instruction in Critical Thinking Strategies on Scientific Argumentation Ability

Explicit Instruction in Critical Thinking Strategies was the weakest among the three predictors of the development of the ability to scientific argumentation, but contributed to it significantly. This finding mirrors the result of study of Khishfe's (2021) that systematic CER instruction improves coherence and scientific vocabulary usage in students' arguments. In the same vein, research conducted by Skoumios (2023) revealed that the instruction of evidence assessment skills provided much more validity to student reasoning, which is an aggregation of the results of the current study. Although explicit instruction provides a lesser independent effect compared with SSI or peer discussion, its usefulness is associated with providing analytical tools that students can utilise in the process of learning through the SSI, including discussion with peers (Izquierdo-Acebes & Taber, 2024; Xie et al., 2025). In this way, an explicit teaching of critical thinking could serve as the basis on which other teaching determines the strength of the various teaching strategies.

6. Conclusion

This study aimed to examine how integrating socio-scientific issues, organised peer discussions, and direct teaching of critical thinking affected the scientific argumentation skills of upper primary students in China. The findings demonstrated that each of the three strategies positively affected the argumentation skills, and their effect was significant as SSI integration produced a significant effect, and structured peer discussion followed next, with the effect on the argumentation skills, and Explicit critical thinking instructions had the least significant effect. The findings confirm this

hypothesis by supporting the notion that authentic, context-rich tasks, i.e., SSIs tasks, provide a mighty chance for students to practice and improve argumentation skills. Peer discussions with a structure allow exchanging ideas and getting constructive feedback, also promoting improved quality of reasoning. Although explicit instruction is less potent when used separately, it is highly crucial in instilling some systematised ways of thinking, which students can later use in diverse instances. In total, the research proves that scientific argumentation instruction needs to be a multi-faceted practice that involves authentic contexts, collaborative discussion, and possibly specific skill building. This has consequences on curriculum making, professional development of teachers and classroom practice not only in China but in other settings as well.

6.1. Recommendation

Based on the study's findings, which identified Integration of Socioscientific Issues (SSI) as the strongest predictor of scientific argumentation ability, followed by structured peer discussion and explicit critical thinking instruction, Chinese primary science teachers are advised to prioritise SSI-based lessons as the foundation for developing reasoning skills. These lessons should be consistently followed by structured peer discussions to enable students to articulate, challenge, and refine their arguments collaboratively. To maximise impact, both strategies should be supported by explicit instruction in critical thinking, providing students with systematic tools such as claim–evidence–reasoning frameworks. Curriculum designers should embed all three elements into teaching manuals, while teacher education programs should emphasise training in evidence-based reasoning, facilitation of high-quality discussions, and scaffolding techniques that align with the demonstrated effectiveness of these approaches.

6.2. Practical Implication

With the help of the study, it is possible to formulate science lesson plans that would strike a balance between content knowledge and reasoning. As an example, a unit introduction of environmental science may focus on including a local SSI, use well-guided group discussions to investigate the presence of multiple perspectives, and give concrete instructions to the students about how to make links between evidence and claims. Such a combined strategy can assist students not only to get stronger in their argumentation but also to learn how to apply scientific thinking to practical problems.

6.3. Limitations

Despite the accomplishment of the objectives of the study, the limitations are as follows: it was based on self-reported data, a factor that can be affected by social desirability, and has a cross-sectional design, hence does not permit the establishment of cause-and-effect relationships. Moreover, the sample was selected from two schools, therefore, having little generalizability to the other regions in China. The potential prospective studies that may be conducted include larger samples of different groups of people using either longitudinal or experimental designs to ensure stronger causal reasoning and flexibility in application.

6.4. Project Funding

China Education Science “14th Five-Year Plan” 2023 Annual Research Project: “Strategic Innovation Research on Integrating the Spirit of Scientists into Primary and Secondary School Science Education” (BHA230126)

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Appendices

Appendix 1: Questionnaire Survey Demographic Questions (3 items)

Grade: 4 to 6

Age: 10-15 years

Gender:

1. Boy
2. Girl

Questionnaire Items (Likert 1–5)

IV1: Integration of Socio-scientific Issues (SSI) in Lessons

- We often discuss real-life issues (e.g., environment, health, technology) in science class.
- I use examples from the news or daily life to think about science problems.
- Our science lessons connect what we learn to community or world issues.
- The science topics we learn have nothing to do with daily life.
- We compare different viewpoints on real-life science problems in class.

IV2: Structured Peer Discussion Activities

- In science class, we have smallgroup discussions with clear steps or roles.
- I get enough time to explain my ideas to classmates during group work.
- Our teacher gives sentence starters or question prompts for discussions.
- Group talks are confusing because there are no rules.
- Discussions with classmates help me improve my ideas.

IV3: Explicit Instruction in Critical Thinking Strategies

- Our teacher shows us how to make a claim, use evidence, and give reasoning.
- We learn how to judge whether evidence is strong or weak.
- We practice finding assumptions or mistakes in arguments.
- We use checklists or rubrics to plan and check our arguments.
- We are expected to figure out how to argue without any guidance.

DV: Scientific Argumentation Ability (SelfPerceived)

- I can make a clear claim and support it with evidence in science.
- I can explain why my evidence connects to my claim (reasoning).
- I can look at different sides of an issue and respond to counterarguments.
- After feedback, I can revise my argument to make it stronger.
- I find it hard to explain why my evidence supports my claim.