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CORRELATION BETWEEN TEACHERS' DISCOURSE STRATEGIES AND THE QUALITY OF STUDENTS' SCIENTIFIC DISCOURSE IN WHOLE-CLASS TEACHING

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Abstract. *Teachers' discourse is instrumental in facilitating the emergence of students' scientific discourse. Many studies have shown that teachers' cognitive demand levels and discursive moves are the main factors in eliciting students' scientific discourse, but few focus on whole-class (non-grouped) teaching settings. This research explored the correlation between teachers' discourse strategies (the cognitive demand of questions and discursive moves) and students' scientific discourse quality in whole-class teaching without intervention. Applying the chi-square test, correspondence analysis, and content analysis, the study revealed the correlation structure between teachers' discourse strategies and students' scientific discourse quality. The teachers' lower (remembering and understanding) cognitive demand questions, primarily elicited students' low-quality (everyday discourse and elementary) scientific discourse responses. High (analyzing and creating) cognitive demand questions, primarily elicited students' high-quality (moderate and advanced) scientific discourse responses. The teachers' discursive moves also elicited students' high-quality scientific discourse, particularly following the teacher's high cognitive demand questions. High-control discursive moves (e.g., "providing opinion") elicited students' moderate scientific discourse responses, and low-control discursive moves ("allocation and organization") elicited students' moderate and advanced scientific discourse responses. Based on these findings, suggestions were made for science teachers.*
Keywords: *scientific discourse, whole-class teaching, teacher's question, cognitive demand, discursive move*

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Introduction

Since the concept of scientific literacy was introduced, it has garnered widespread attention from researchers and educators, significantly impacting science education globally. Currently, scientific literacy is one of the main goals of science education, improving the scientific literacy of citizens is the fundamental purpose of science education (Norris & Phillips, 2003; Yacoubian, 2018). Scientific literacy refers to the essence of scientific exploration, being able to use scientific concepts in daily life, and being able to read and interpret scientific information in mass media (Gillies & Baffour, 2017; Wallace, 2004). Rennie considered that people with scientific literacy include those who: 1) are interested in and understand the world around them; 2) engage in the discourse of and about science; 3) are able to identify questions, investigate, and draw evidence-based conclusions; 4) are skeptical and questioning of claims made by others about scientific matters; 5) make informed decisions about the environment and their own health and well-being (Rennie, 2005, p. 11). Among these abilities, scientific discourse plays a vital role (Norris & Phillips, 2003), and even scientific literacy can be understood as a language ability. Therefore, to cultivate students' scientific literacy, teachers need to promote the use of scientific discourse among students and help them effectively participate in scientific discussions.

Existing research has suggested that the most effective way to develop children's scientific discourse is practice-based teaching, but the effectiveness of this way still depends on the quality of classroom dialogue (Gillies & Khan, 2009; Soysal, 2021b). Teachers' discourse is a major factor influencing students' scientific discourse. Researchers have explored the relationship between different types of teachers' discourse and the production of students' scientific discourse, but often focus on the context of teaching interventions such as group inquiry and cooperative learning (Gillies & Khan, 2009; Lee & Irving, 2018). Few studies focused on naturalistic classrooms (Soysal, 2021a), and even fewer considered the teaching realities of large class sizes in East Asia and Europe. The limitations of existing research indicate the lack of suitable

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guidance and measures to help teachers in large classroom settings improve their discourse. To resolve this issue, this study explored the correlation between teachers' discourse and students' scientific discourse in a whole-class teaching setting without grouping. This aimed to identify the parts of the teachers' discourse strategies that have promoted meaning and to help teachers improve their classroom discourse.

Scientific Discourse and the Level of Students' Scientific Discourse

Discourse is a medium for people to participate in social life and a tool for constructing social life. As a fusion of socially acknowledged methods of using language, ways of conceptualizing, and modes of communication, discourse can be utilized to validate one's membership in a socially significant group (Gee, 2004). Dewey's view on learning illustrates the important role of discourse, "Learning, in the proper sense, is not learning things, but the meanings of things, and this process involves the use of signs, or language in this generic sense" (Dewey, 2018, p. 164). Knowledge is constructed through the interaction of discourse and other symbolic media within the social context. Discourse functions both as a medium for social interaction and as a vehicle for knowledge transmission. In essence, to learn a subject is to master the discourse of that subject's community (Norris & Phillips, 2003; Wallace, 2004).

In his work *Talking Science: Language, Learning, and Values*, Lemke posited, "Learning science means learning to talk science. It also means learning to use this specialized conceptual language in reading and writing, in reasoning and problem-solving, and in guiding practical action in the laboratory and daily life" (Lemke, 1990, p. 1). From this perspective, scientific dialogue differs from conventional social interactions. It emphasizes the shared construction of knowledge and comprehension, necessitating the ceaseless negotiation of meanings to cultivate reciprocity and mutuality (Mercer, 2010). Furthermore, scientific dialogue employs scientific discourse to construct meanings consistently. Scientific discourse entails the processes or methods of discussing scientific information, theories, or practices, often involving explanation, reasoning, modeling, evaluation, and so on (Grimes et al., 2018; Lee & Irving, 2018). Hence, students' discourse in the classroom should embody two aspects, dialogue with others and integration with scientific content. Students need to contribute to the collective process of constructing scientific meanings.

In an early study, students' discourse in the science classroom was categorized as detailed explanation, questioning, succinct responses, engagement, guidance, and interruption (Gillies, 2004). This categorization primarily analyzed students' discursive moves without adequately integrating scientific content. Similarly, another research devised an analytical framework for students' discourse during discussions, categorizing it into thought and reasoning, complete thought, word/phrase, and no response (Pimentel & McNeill, 2013). Subsequently, a framework to assess the scientific level of students' discourse was introduced, comprising the following levels: social language; basic statements; basic use of scientific language; moderate use of scientific language; and advanced scientific language (Gillies et al., 2015). Students' discourse in science classrooms represents a continuum from silence to engaging in dialogue in a scientific manner. This framework can systematically encapsulate varying levels of students' scientific discourse in the science classroom.

The Facilitative Role of Teachers' Discourse

Literature has indicated that involving students in real practice activities benefits the development of their scientific discourse. In group collaborative work, students' social discourse and scientific discourse have increased (Grimes et al., 2018; Kulatunga et al., 2013). However, previous research found that cooperative learning promotes students' discourse production; the level of students' complex thinking like problem-solving and reasoning still depends on specific teachers' discourse strategies (Gillies & Khan, 2009). Without continuous and effective interaction, students tend not to elaborate on information spontaneously, pose thought-provoking questions, or utilize prior knowledge (King, 2002). Similarly, researchers found that coordinating theory and evidence, hypotheses, and problems is challenging for students unless supportive tools or guidance are provided (Herrenkohl et al., 2011; Kuhn, 1993). The key to developing students' scientific discourse lies in the specific discourse support of teachers in teaching interactions. Therefore, teachers need to be aware of the differences and roles of their discourse to support students' effective participation in scientific dialogue (Bansal, 2018; Lee & Irving, 2018).

The literature has pointed out that the IRE/F discourse structure of teachers' initiation, students' response, and teachers' evaluation or feedback is a typical classroom dialogue structure and still dominates (Geelan, 2013). Classroom discourse is predominantly driven by teachers and initiated through their act of posing questions. A significant number of researchers have mentioned that the cognitive demands of teachers' questions are among

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the factors affecting students' discourse (Chin, 2006; Smart & Marshall, 2013; Tagnin et al., 2021). According to their cognitive demand level, questions can be divided into two categories: low-demand questions and high-demand questions (Tagnin et al., 2021). Low-demand cognitive questions prompt descriptions of events, scientific terms, and statements, and invoke cognitive processes like memorizing, understanding, and application, which do not change the pre-existing knowledge structure. Conversely, high-demand cognitive questions require students to engage in higher-level cognitive activities such as analysis, creation, and evaluation, leading to the construction of viewpoints and plans. Researchers have found that high-demand cognitive questions can promote students' high-demand thinking and dialogic participation (Soysal, 2021a; Tagnin et al., 2021). The literature also mentioned that when teachers' questions had a low (e.g., understanding) cognitive demand, students' arguments were at the highest level (Soysal, 2021a).

In addition to questioning strategies, teachers can still use other discourse strategies to promote students' higher-level scientific discourse. When teachers effectively use the E/F position in the IRE/F structure, they create more dialogue possibilities and enhance the complexity of students' discourse (Wells, 1993). Researchers referred to the teachers' follow-up actions after students' responses as discursive moves, which might include forms such as feedback, evaluation, requests for detailed explanations, or non-verbal behaviors (Bansal, 2018; O'Connor & Michaels, 2015; O'Connor & Michaels, 1996). Furthermore, teachers' discursive moves may involve monologic and dialogic instructional purposes (Soysal, 2021c, p. 230). The former is that teachers provide information, opinions, or knowledge for public discourse space (Soysal, 2021b), while the latter is that teachers promote students' discourse interaction and intelligent contribution to classroom conversations (Soysal, 2021c). A series of studies have found different teacher discursive moves and elucidated their positive role in promoting classroom dialogue, such as "revoicing", "saying more" (O'Connor & Michaels, 1996), and "marking" (McKeown & Beck, 2004). So, generally, the discursive move is a kind of teacher intervention behavior that can promote student participation in classroom dialogue (Mortimer, 2003). As an effective tool, teachers can use and need to learn how to use discursive moves to continuously support and organize classroom micro-interactions (O'Connor & Michaels, 2015).

Purpose and Research Questions

Previous research has indicated that the cognitive demands of teachers' questions and discursive moves are key factors affecting students' discourse in teaching interactions. It is still unclear about the correlation between the cognitive demand of teachers' questions, teachers' discursive moves, and the level of students' scientific discourse. The existing studies have mainly focused on ideal teaching situations created by researchers, such as group collaboration and inquiry teaching; however, research focusing on whole-class teaching in large-scale class is still limited. Therefore, this study made up for the shortcomings of the existing research and explored the correlation between teachers' discourse strategies (cognitive demand of teachers' questioning and teachers' discursive moves) and students' scientific discourse quality under the background of whole-class teaching in large-scale class. Additionally, it provided guidance for teachers to improve their discourse in teaching interaction. Specifically, this study answered the following research questions:

(1) What is the correlation between the cognitive demands of teachers' questioning and discursive moves with the quality of students' scientific discourse?
(2) Which types of teachers' discourse strategies can trigger students' advanced scientific discourse?

Research Methodology

Background

This study explored the correlation between the cognitive demand of teachers' questioning, discursive moves, and the quality of students' scientific discourse in whole-class (non-grouped) teaching involving large-scale classes. Considering the representativeness of the sample, suitable participants were selected. Beginning in early September 2023, with the informed consent of the participants, the researcher entered the science classrooms for observation and collected teaching videos, which lasted for nearly four months. During the research process, the researcher did not provide any support to the teacher, and the teacher independently conducted classroom teaching. The teacher's discourse strategies and students' scientific discourse quality encoding in this study were qualitative categorical variables, which were suitable for correlation judgment using the chi-square test and correspondence analysis and explained through content analysis. Overall, this was a study conducted in a naturalistic

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manner, and the teacher's discourse strategies that can trigger the production of advanced scientific discourse in students are all derived from the teaching habits of the teacher.

Participants

The participants in this study included a lower-secondary school science teacher from Zhejiang Province, China, who has four years of experience in science teaching, along with 50 students from her class, representing the total enrollment of that class. In China's current basic education system, large classes are prevalent. Additionally, due to the pressure of exams, most teachers primarily employ lecture-based teaching methods. To explore the correlation between teachers' discourse strategies and the quality of students' scientific discourse in the context of whole-class teaching and large-scale class, purposive sampling was used in the selection process of participants in this study. Firstly, Zhejiang Province is the earliest province in China to adopt and still implement a comprehensive science curriculum, which has been in place for over twenty years. Compared to other regions where lecture-based teaching remains dominant in China, science teaching in Zhejiang is currently undergoing reforms. Secondly, the school is at a moderate level in the city, enrolling students for specific streets and districts, which means that its students can, to some extent, represent the general academic level of middle school students in Zhejiang Province. Thirdly, the teacher had obtained a master's degree in subject teaching with a specialization in science education. Compared to teachers who had not participated in the comprehensive science teacher training program, this teacher was more likely to promote students' participation in classroom discourse through her daily teaching practices. In addition, the researcher established a long-term relationship with the teacher, which facilitated the development of the research process.

The Level Division for Students' Scientific Discourse

Students' scientific discourse analysis framework was employed as the initial coding tool (Gillies et al., 2015). During the iterative coding process, this framework was adjusted based on the study's data to better adapt to the analysis of the quality of students' scientific discourse in whole-class teaching (see Table 1).

Table 1
Framework for Analyzing Students' Scientific Discourse Quality

Non-scientific discourse	Description
Level 1 silence	Refers to the situation where, after a teacher's question, silence ensues for 2 seconds or more before the teacher continues speaking. This is interpreted as a student's silent response in the conversational turn.
Level 2 negative responses	Refers to minimal engagement responses, such as simple "yes" or "no" answers or parroting the teacher's words without additional opinion.
Level 3 everyday discourse	Refers to the usage of everyday information and knowledge to answer or pose questions. For example, "It's round".
Scientific discourse	Description
Level 4 elementary scientific discourse	Refers to the description of phenomena that do not take a propositional form; accurate presentation or application of previously learned scientific knowledge in brief responses; posing open-ended questions about the topic to seek explanations or clarifications; presenting ideas supported by reasons. For example, "The edges of two adjacent continents fit together, and there are no gaps in between".
Level 5 moderate scientific discourse	Proposes propositions based on the teaching theme content; makes basic evaluations of representations; provides evidence or explanations and clarifications based on scientific knowledge; proposes strategies to verify information; participates in ongoing communication, clarifying or supplementing own views or the views of others. For example, "What he means to say that the Sun is here, the Earth is next to it, and then the Moon moves to this position. It's the Moon, not the Earth, that blocks the light, and this cannot prove that the Earth is round".
Level 6 advanced scientific language	Speculates with evidence; presents claim and uses reasoning to establish connections between claim and evidence; provides reasons to question or support others' claim. For example, "But, if it were to be orbiting around the Earth, its size couldn't be much larger than the Moon's. At that time, the (Moon's) gravity (on it) wouldn't be stronger than the Earth's (gravity on it). It would only be a sixth, nowhere near enough to hold it. It would have taken off somewhere you wouldn't know".

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The Types of Teachers' Discourse Strategies

Teachers play a crucial role in pedagogical dialogue, as they initiate and drive the conversation forward by posing follow-up questions or employing other discursive moves. To thoroughly explore the correlation between teachers' discourse strategies and the quality of students' scientific discourse, this study analyzed teachers' discourse strategies including teacher questioning and discursive moves. The revised Bloom's taxonomy was used to analyze the cognitive demand level of teachers' questions (Soysal, 2021a). Regarding teachers' discursive moves, the previous research findings were adopted as a preliminary analytical framework (McKeown & Beck, 2004; O'Connor & Michaels, 1996). Through iterative coding, an analytical tool tailored to our dataset for examining teachers' discourse strategies was developed (see Table 2).

It's important to emphasize that the distinction between various discursive moves lies in the extent of teachers' involvement in the classroom dialogue. For instance, "provide opinion (T9)" refers to teachers' using subjective statements or analyses to respond to students, which often stimulate further discussion. "Positive emotion (T8)" refers to teachers' acknowledging students' effective contributions to the classroom dialogue, indicating teachers retain the right to evaluate. "Allocation and organization (T11)" is a type of discursive move in which teachers do not intervene in thematic discussions. The main purpose of this move is to promote student participation in the classroom and foster the continuity of viewpoints among students. This move highlights the role of the teacher as the "facilitator" of classroom dialogue, responsible for arranging and organizing classroom interactions.

Table 2
Framework for Analyzing Teachers' Discourse Strategies

Question cognitive demand	Description
T1 remember	Retrieves relevant knowledge or information from long-term memory. For example, "Where does the Earth rotate around".
T2 understand	Determines the meaning of instructional information, including verbal, written, and graphic communication, requires students to interpret, summarize, classify, and compare the information that has been presented. For example, "So, what is the function of these latitude and longitude lines?"
T3 apply	Executes or uses a procedure in a given situation.
T4 analyze	Breaks down materials into their constituent parts and detects the relationships among the parts and between the parts and the overall structure or purpose. For example, "Are there any points in this fact that make you question?"
T5 evaluate	Makes judgments based on standards and norms, such as determining whether evidence is valid, whether a plan can verify a problem, and whether a viewpoint is credible. For example, "Which categories do you think are more appropriate, more in-depth, and able to grasp some of the essence?"
T6 create	Combines different information or elements to form a novel, coherent whole or create an original product. For example, constructing an experimental plan based on an inquiry problem, or proposing a viewpoint by synthesizing existing information. For example, "What comes to mind when you want to explore this problem?"
Discursive move	**Description**
T7 action command	Requires students to make a behavioral response, such as conducting observations or operations.
T8 positive emotion	Directly provides positive emotional feedback, encouraging the student to further supplement; the teacher indicates that he/she did not understand, which indirectly provides positive feedback. For example, "Um, good, very good."
T9 provide opinion	Participates in dialogue, expressing personal opinions rather than factual knowledge on the topic of conversation. For example, "You represent possibility, but all possibilities must be scrutinized by facts, and must undergo theoretical scrutiny."
T10 prompt	Based on the question, provide half of the answer or content that is closely related to the answer, as a hint for students. For example, "Every month, it happens. The moon waxes and wanes, as the ancients have long discovered. Our moon waxes and wanes, but who caused this waning?"
T11 allocation and organization	Revoicing expresses an implicit communicative meaning by repeating the student's discourse, such as, "Do you think there must be a lot of organisms in places like the Earth's crust?" Establishes a relationship for the speaker based on the presented discourse, such as, "She is standing on his side again"; shifts the subject of the discourse towards others, seeking their understanding, such as, "Do you understand what she means?"

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Data Collection and Analysis

With the informed consent of the participants, the researcher entered the science classroom as an observer and collected teaching videos, which lasted for nearly 4 months. To better answer the research questions, the following standards for video selection were applied: 1) Students' discourse entries account for more than a third of the total; 2) The videos exhibit a diversity of student discourse, including instances of moderate and advanced scientific discourse. Then, according to the transcription standards in Table 3 (Wieselmann et al., 2021), three classroom teaching videos were transcribed, resulting in 788 utterances between teacher and students. The teacher's utterances accounted for 52% of the total. Based on the research questions, preliminary analysis and screening were conducted on the dataset. Dialogues not related to science content, such as class affairs, were removed, as well as monologues by the teacher. A total of 446 classroom utterances were coded as categorical variables for this study (223 each for the teacher's and students' utterances). Cohen's Kappa, a robust statistic for measuring inter-rater reliability for categorical data, indicated good reliability between the coders ($\kappa = .828$). All disagreements were resolved through discussion.

Table 3
Transcription Key

Symbol	Meaning	Example
( )	Parentheses indicate silence; timed in seconds or untimed indicated by a period in parentheses	Um (.) Okay.
( )	Parentheses with text indicate a supplement to oral language to make it more understandable	If (the land) were flat,

Teacher-student utterances in this study were coded as qualitative variables. The chi-square test can generally indicate whether there is a significant difference between two variables, but further analysis is still needed to accurately determine the correlation between the categories of the two variables. Correspondence analysis can solve this problem. Correspondence analysis is a qualitative-dominated cross-analysis technique that normalizes contingency tables to obtain corresponding matrices, which are then subjected to singular value decomposition (de Nooy, 2003; Kutscher & Howard, 2022). Through these processes, the correlation between qualitative data is expressed in a reduced dimensional visual space map. The larger the singular value in a dimension, the more data variability is explained. Generally, the first two dimensions contain most of the inertia (variation) in the data. Greenacre provided a comprehensive description of the concept and mathematical foundation of this method (Greenacre, 2017). In summary, correspondence analysis can reduce the dimensionality and visualize the correlation between high-dimensional categorical variables in data. By observing the angles between vectors and the length of the vectors' projection in the corresponding map, researchers can determine the similarity or correlation between the two categorical variables. It should be noted that the correlation between variables obtained through position and distance in the correspondence analysis map is always determined compared to other points (Greenacre, 2017, p. 272).

This study utilized the Statistical Package for Social Science (SPSS) version 27.0 for data statistical processing. Firstly, a chi-square test was used to determine whether there was a significant difference between teachers' discourse strategies and students' scientific discourse quality. Then, correspondence analysis and content analysis were employed to explore the specific correlations between teachers' discourse strategies and the quality of students' scientific discourse.

Research Results

"Remembering" Cognitive Demand Questions Predominated Teachers' Discourse Strategies

As shown in Table 4, the majority of the teacher's questions were at the remembering level of cognitive demand (23.8%), followed by the understanding level (13.9%). The teacher's discursive moves of "allocation and organization (T11)" account for approximately 13.9%, with "action command (T7)" slightly lower at around 13.5%. This suggests that the teacher's questions were primarily focused on students' understanding and memorization of knowledge

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and information. Additionally, the teacher used various follow-up moves such as "positive emotion", "prompt", and "allocation and organization" to promote students' classroom discourse participation. These teacher's discursive moves make up 42.6% of the total teacher discourse. However, the effectiveness of these actions was not entirely satisfactory, as confirmed by data on the distribution of students' scientific discourse.

The statistical result shows that with the overall distribution of teacher's discourse strategies, elementary scientific discourse was the most common response of students (Table 5). Students' elementary scientific discourse is the most frequent (35.9%), followed by everyday discourse (29.1%). Silence and negative responses account for approximately 11.2% of the total student discourse, while moderate and advanced scientific discourse accounts for about 23.7%. This shows that students could participate in the dialogue, but they mainly used everyday discourse and elementary scientific discourse.

Table 4
Distribution of Teacher's Discourse Strategies

Question	Remember (T1)	Understand (T2)	Apply (T3)	Analyze (T4)	Evaluate (T5)	Create (T6)
Frequency (Percentage)	53(23.8%)	31(13.9%)	14(6.3%)	3(1.3%)	17(7.6%)	10(4.5%)
Discursive move	Action command (T7)	Positive emotion (T8)	Provide opinion (T9)	Prompt (T10)	Allocation and organization (T11)	
Frequency (Percentage)	30 (13.5%)	9 (4.0%)	13(5.8%)	12(5.4%)	31(13.9%)	

Note: The number of teacher's discourse codes is n = 223.

Table 5
Distribution of Students' Science Discourse Levels

Student discourse	Silence	Negative responses	Everyday discourse	Elementary **scientific**	Moderate **scientific**	Advance **scientific**
Frequency (Percentage)	7 (3.1%)	18 (8.1%)	65 (29.1%)	80 (35.9%)	34 (15.2%)	19 (8.5%)

Note: The total number of students' discourse codes is *n* = 223.

Teachers' Discourse Strategies Showed Significant Differences in the Quality of Students' Scientific Discourse

A chi-square test was performed to test the difference between teachers' discourse strategies and students' scientific discourse quality. The results indicated a significant difference between the teacher's discourse strategies and students' scientific discourse quality ($p < .01$), allowing for the rejection of the null hypothesis. Additionally, the strength of the correlation was highlighted by the Contingency Coefficient ($C = .626$), indicating a strong correlation between the teacher's discourse strategies (cognitive demand levels of the teacher's questions and discursive moves) and students' scientific discourse quality.

The Correlation between Teachers' Discourse Strategies and Students' Scientific Discourse Quality

The correspondence analysis was employed to examine the correlation between various categories of the two variables: the teacher's discourse strategies and students' scientific discourse level. Given the research question, discourse codes unrelated to student's scientific discourse were excluded, involving "silence" and "negative response". Then, the corresponding analysis was conducted using the teacher's discourse strategies as row points and students' scientific discourse levels as column points.

Table 6 shows the statistical results of the corresponding analysis ($\chi^2 = 113.208$, $p < .001$), which indicates a significant correlation between the two category variables, making it appropriate to proceed with the correspondence analysis. As shown in Table 6, the total inertia is 0.572. The inertia of Dimension 1 is 0.377 (65.9%), and the

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inertia of Dimension 2 is 0.158 (27.6%). The two dimensions' inertia amounted to 0.535, accounting for 93.5% of the total inertia. This suggests that the two-dimensional correspondence map explains 93.5% of the data's variation, with minimal information loss. Moreover, as shown in Table 7 and Table 8, the contribution of two dimensions to the inertia of each point is greater than .50, all points are well represented in the first two dimensions. Essentially, the first two dimensions map can adequately illustrate the specific correlation between the teacher's discourse strategies and students' scientific discourse quality.

Table 6
Summary of Correspondence Analysis Statistical Results

Dimension	*SV*	*I*	Prop. of I	χ^2	*p*
1	.614	0.377	.659		
2	.397	0.158	.276		
3	.192	0.037	.065		
Total		0.572	1	113.208	< .001

Note: SV = Singular Value; I = Inertia; Prop. of I = Proportion of Inertia; df = 30.

Table 7
Contribution of Two Dimensions to Inertia of Row Point

Row Point	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
Contribution	.942	.981	.760	.996	.620	.997	.593	.997	.966	.987	.999

Table 8
Contribution of Two Dimensions to Inertia of Column Point

Column Point	Everyday	Elementary	Moderate	Advanced
Contribution	.789	.776	.992	.988

Observing the corresponding analysis map (Figure 1), it can be found that the points representing students' scientific discourse level are distributed on both sides of the centerline of the vertical axis. Points "Everyday" and "Elementary" are located on the left-hand side, while "Moderate" and "Advanced" are located on the right-hand side. This indicates that the scientific discourse level of students was divided into two groups with significant differences. On the left-hand side, the teacher's discourse strategies T1 (remember), T2 (understand), T3 (apply), T7 (action command), and T10 (prompt) are displayed, along with the student scientific discourse levels "everyday" and "elementary". On the right-hand side, the teacher's discourse strategies T4 (analyze), T5 (evaluate), T6 (create), T8 (positive emotion), T9 (provide opinion), and T11 (allocation and organize) are displayed, accompanied by the student's scientific discourse levels "moderate" and "advanced". This means that overall, teacher posing high (analyze, evaluate, and create) cognitive demand questions and using specific discursive moves (except the "action command" move) tended to elicit advanced scientific discourse from students.

However, the correlation between teacher's discourse strategies and students' scientific discourse levels required further exploration through analyzing the corresponding analysis map. According to the research of Greenacre (2017), the strength of the correlation between row and column points can be concluded by the scalar product of the vector pointing from the origin to the row and column points. The longer the projection length of a row vector on a column vector, the stronger the correlation, while the shorter the projection length, the weaker the correlation (Greenacre, 2017, p. 98). Suppose the projection of the row vector on the column vector is located on the reverse extension line of the column vector (the angle between the two vectors is greater than 90 degrees). It means a negative correlation between the two categories represented by row and column points. Based on this, the vectors from the origin to column points ("Elementary", "Moderate", and "Advanced") were employed as a reference. The strength of the correlation between different categories of teacher discourse strategies and the level of students' scientific discourse was identified based on the length of their projection onto the column vector.

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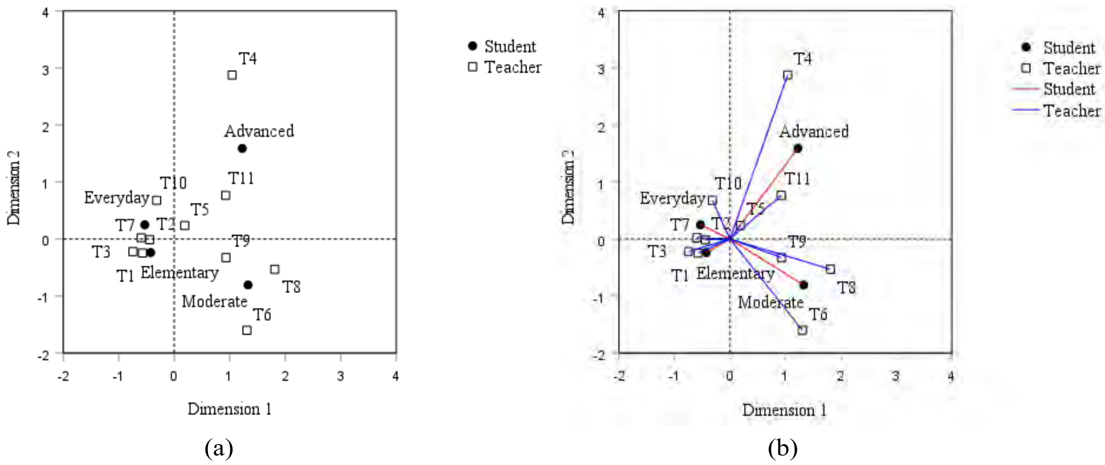
Figure 1
Corresponding Analytical Map



1. Questions with Low Cognitive Demands Elicit Elementary Scientific Discourse from Students

To further analyze which teacher discourse strategies were closely correlated with students' elementary scientific language, the vector "Elementary" was employed as a reference. The projection direction and the length of teacher discourse strategy vectors onto this "Elementary" vector were then observed. As shown in Figure 1 (b), the projection positions of vectors T1, T2, T3, and T7 are in the positive direction. The projection lengths in descending order are vectors T3, T1, T7, T2. This means that teacher questioning at the cognitive demands level of applying, remembering, and understanding, triggered students' elementary scientific discourse. Compared to other teachers' discourse strategies, there was the strongest correlation between the teachers' questioning of applying cognitive demand level and the students' elementary scientific discourse responses. The projections of T5 and T10 are located on the reverse extension line of this vector, which means they were negatively correlated with students' elementary scientific discourse.

Content analysis of teacher-student dialogues also supported this finding. The students' responses were observed as everyday discourse or simple academic vocabulary when the teacher's questions were at low (remember, understand, and apply) levels of cognitive demand. In the excerpted dialogue segment in Table 9, the teacher posed three questions at the remembering level of cognitive demand (01, 09, 11), which received responses from students in everyday discourse (02, 10) and elementary scientific discourse (12). The teacher asked students about "the changes in their field of vision during the process of climbing high places" (01) or "the method should be used when real experiments cannot be conducted" (11). These questions elicited students to draw upon their existing experience or knowledge. Although questioning with low cognitive demand provided opportunities for students to participate in classroom conversations, this type of classroom interaction mainly did not trigger students' high-level scientific discourse.

2. Questions with Creating and Analyzing Cognitive Demands Elicit Students' Moderate and Advanced Scientific Discourse

To further analyze which teacher discourse strategies had a strong correlation with students' advanced scientific discourse, the vector "Moderate" was employed as a reference. The projection direction and the length of teacher discourse strategy vectors onto the "Moderate" vector were then observed. As shown in Figure 1(b), the projections of teacher discourse strategy vectors on the "Moderate" vector are in the positive direction. In descending order, the projection lengths are vectors T6, T8, T9, and T11. This means these teacher discourse strategies were positively correlated with students' moderate scientific discourse responses. Compared to these teacher discourse strategies, teacher questioning at the creating(T6) cognitive demand level strongly correlated with students' moderate scientific discourse. The teacher's discursive moves "positive emotion (T8)", "provide opinion (T9)", and "allocation and organization (T11)", also triggered students' moderate scientific discourse responses.

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Using the vector "Advanced" as a reference, the projection of teacher discourse strategy vectors onto vector "Advanced" are in the positive direction and the projection lengths in descending order are vectors T4, T11, T8. The remaining T10, T5, and T9 are shorter and closer to each other in length. This means that these teachers' discourse strategies were positively correlated with students' advanced scientific discourse. In addition, compared to these teachers' discourse strategies, teacher questioning at the analyzing (T4) cognitive demand level had the strongest correlation with students' advanced scientific discourse. The teacher's discursive moves "allocation and organization (T11)" and "positive emotion (T8)" followed. The "prompt" move, "provide opinion" move, and questions at the cognitive demand level of evaluating also elicited students' advanced scientific discourse responses, but their correlations with students' advanced scientific discourse were weakest.

Content analysis of teacher-student dialogues also supports these findings. The students' responses were observed at high levels (moderate and advanced) of scientific discourse when the teacher used high (analyze and create) cognitive demand questions. As shown in Table 9, the teacher's question at the creating level of cognitive demand (07) hoped that students construct a research plan to explore whether "To see a thousand miles, ascend another floor" can explain that the Earth is a sphere. A student proposed a hypothesis using everyday discourse (08), which was a restatement of the information already presented in the previous conversation. To publicize the information "use simulation experiments", the teacher initiated two questions at the remembering level of cognitive demand (09, 11). Following this, the teacher restated the initial question (07) at the creating level of cognitive demand (13), which triggered the student's response using moderate scientific discourse (14). Immediately following, the teacher triggered the student to propose a plan (16) with "allocation and organization" (15), and the teacher gave "positive emotion" feedback (17), which elicited the student to clarify and supplement the proposed plan (18).

Table 9
Classroom Dialogue Segment

Turn Number	Excerpt	Code
01	T: There's a saying that goes, "If you wish to see farther, climb to a higher level." So, what happens to the range of what you can see when you go higher?	T1 remember
02	S: The broader.	L3 everyday discourse
03	T: Do you think this statement has any relation to the shape of the Earth?	T5 evaluate
04	(2)	L1 silence
05	T: If the Earth were flat, like the ancient saying "the sky is round and the Earth is square," would the higher you go mean you could see a broader range? Or is it only when the Earth is a sphere, a curved surface, that the higher you go, the further you can see?	T9 provide opinion
06	(3)	L1 silence
07	T: What comes to mind when you want to explore this question?	T6 create
08	S1: Um (.) it's just(.) I was thinking that (.) if (the land) were flat, looking out from a tall building, I think it might be the same.	L3 everyday discourse
09	T: So, do we have a chance to find a flat Earth to climb up and see?	T1 remember
10	S: Impossible.	L3 everyday discourse
11	T: Um, no, we can't. It's impossible to explore. So, what can we turn to at this point?	T1 remember
12	S: A simulation experiment.	L4 elementary scientific
13	T: We can also conduct simulation experiments or use models, we can directly use images. So, how can we use images to explore?	T6 create
14	S2: We can draw a straight line on the blackboard now, and then draw a person on it. Then, looking at that person, the point you see might be at a lower place. This is looking down from a high place, and then what you see from a low place with this high place (in comparison).	L5 moderate
15	T: Do you understand?	T11 allocation and organization

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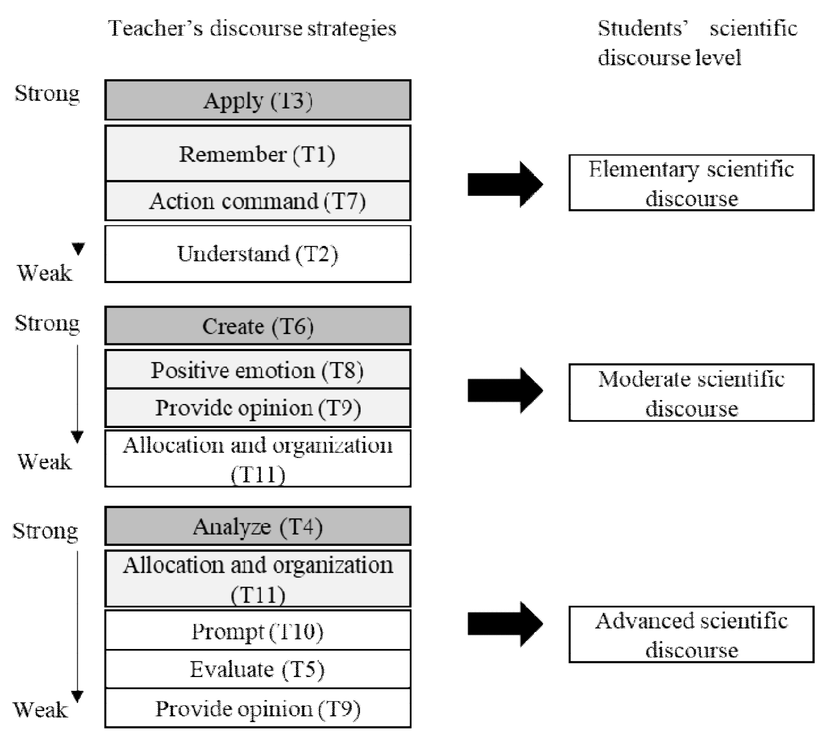
Turn Number	Excerpt	Code
16	S3: I think it's like assuming you have a range of vision from this eye. It's about whether you can see the same object from a lower position as you can see from a higher position. If you can see it from both positions, it means that the places you can see from a high position are not visible from a low position, which can prove that the Earth is not flat.	L5 moderate
17	T: I'm not quite following, you can draw it.	T8 positive emotion
18	S3: So, this is like a flat surface, right? And there's one person up high, and another one down low. Just imagine they're both in the same building, looking out. If I'm up high and can see certain stuff within this area, and I can see the same things when I'm down low, that's what it would be like if the Earth were round. But if the Earth were flat, then being up high in the same building, I could see up to this point, but being down low, I could only see up to here.	L5 moderate

3. Similarities Exist Among the Types of Teacher's Discourse in Triggering Student Scientific Discourse

Interestingly, the analysis of the corresponding map reveals that specific teachers' discourse strategies shared similarities in triggering students' scientific discourse production. In Figure 1 (b), smaller angles are observed between the vectors T1 (remember) and T3 (apply). Similarly, smaller angles are found between the other two sets of vectors: T2 (understand) and T7 (action command), T8 (positive emotion) and T9 (provide opinion). Smaller angles between the positive vectors of different categories of the same variable suggest a greater similarity between these two categories. Among the eleven teacher discourse strategies, these three sets of teacher discourse strategies shared similarities in triggering students' scientific discourse. Specifically, T1 and T3 are closely related to "Elementary" which means that their function of eliciting students' elementary science discourse was similar. T2 and T7 are located in the middle of "Everyday" and "Elementary" suggesting that they could trigger students' responses using daily and elementary scientific discourse. T8 and T9 are relatively close to "Moderate", which could trigger students' moderate scientific discourse responses. As demonstrated in the dialogue segment in Table 9, the teacher's discursive moves of "positive emotion" (15) and "provide opinion" (17) both preceded instances of students' moderate scientific discourse (16, 18).

Figure 2
The Correlation Structure of Teachers' Discourse Strategies and the Quality of Students' Scientific Discourse



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In summary, the findings indicated a correlation structure existed between teacher's discourse strategies and the quality of students' scientific discourse (Figure 2). Teachers' questions at the applying level of cognitive demand were most likely to elicit students' elementary scientific discourse. Similarly, questions at the creating level were most likely to elicit students' moderate scientific discourse. Finally, questions at the analyzing level were most likely to elicit students' advanced scientific discourse.

Discussion

This study explored the correlation between the teacher's discourse strategies and the quality of students' scientific discourse within the context of large-scale class during whole-class teaching. An analytical framework aligning with the dataset was developed, building upon established research. A chi-square test was conducted to ascertain whether a significant difference existed between the teacher's questions, the teacher's discursive moves, and the quality of students' scientific discourse. Following this, correspondence analysis and content analysis were employed to delve into the specific correlation further.

The Strong Correlation Between High-Demand Cognitive Questions from Teachers' and Students' Scientific Discourse

Consistent with existing research, teachers often use questions that demand "remembering" and "understanding", which are of low cognitive demand (Huang et al., 2019; Saka & Inaltekin, 2023; Soysal, 2021a). This study shows that teachers' discourse strategies were observed at the low (remember, understand, and apply) cognitive demand, nearly half (43.9%) of the total numbers (Table 4). This implies that the teacher initiating dialogue was mainly to check students' knowledge, not to understand their thoughts. Therefore, many students' discourse was observed as non-scientific (40.3%) and elementary scientific (35.9%). Of course, these findings were obtained in large-class size with whole-class (non-grouped) teaching. But, if this non-dialogic authoritative discourse is the only form of classroom dialogue, it will be detrimental to students' meaning construction.

Fortunately, questions with high (analyze, evaluate, and create) cognitive demand were observed in this study, although they only accounted for a small percentage (13.4%) of the total teacher discourse strategies (Table 4). Previous research indicates a direct association between high cognitive demand questions and the complexity of students' scientific discourse, with high-level questions provoking more complex responses, while lower-level questions eliciting simpler ones (Ni et al., 2014; Soysal, 2021a; Tagnin et al., 2021). The findings of this study corroborated the results of previous research. Teachers' high (create, analyze) cognitive demand questions are also strongly correlated with students' high-quality (moderate and advanced) scientific discourse, suggesting that high cognitive demand questions are crucial for fostering high-quality scientific discourse responses in large class sizes with a whole-class (non-grouped) teaching setting.

Functions of Teachers' Discursive Moves

Numerous teacher's discursive moves were found in the dataset, accounting for 43.6% of the total teacher discourse. Notably, the discursive moves of "allocation and organization" appeared frequently, making up 13.19%. This demonstrates that the teacher's practice in China is not just seemingly participatory teaching (Huang et al., 2019), but actively uses discursive moves to facilitate students' contributions to knowledge production (Figure 2). As shown in Table 9 through content analysis, the teacher's discursive moves elicited students' high-quality scientific discourse, particularly following the teacher's questions of high cognitive demand. It is reasonable to infer that students struggled when they faced questions of high cognitive demand, at this point, the teacher's subsequent discursive moves served as a supportive scaffold (van de Pol et al., 2018).

This study shows that teacher discursive moves fostering student scientific discourse production included "prompt", "provide opinion", "positive emotion", and "allocation and organization". People interact in discourse to construct meaning, negotiate, and explore their identities (Mercer, 2010). Halliday pointed out that discourse has the following functions: the conceptual function of conveying information; the interpersonal function of expressing emotions, attitudes, and acting on others; and the cultural function of constructing activities that conform to specific communities (Halliday, 1993). These discursive moves observed in this study primarily served cognitive, interpersonal, and cultural functions in organizing and coordinating scientific dialogue. "Prompt" and "provide opinion" constitute cognitive support provided by the teacher, intended to enable students to construct or re-

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fine a complex cognitive process by incorporating new perspectives or information. "Positive emotion" offered interpersonal affirmation and encouragement, stimulating student participation in the dialogue. "Allocation and organization" move denoted the teacher's deliberate withdrawal from the conversation. In this move, the teacher assumed the role of a facilitator, rather than a dictator of the discussion. This discursive move indicated that the level of teacher control diminished, transitioning from providing viewpoints and support to delegating the responsibility of knowledge production to the students.

This study reveals that teacher discursive moves with higher control (such as "provide opinion") were closely correlated with moderate-level student scientific discourse, and those with lower control (such as "allocation and organization") were closely correlated with both moderate and advanced-level student scientific discourse. Based on these findings, in whole-class teaching (not grouped), to enhance students' production of moderate and advanced scientific discourse, teachers should design and use high cognitive demand questions, and flexibly employ discursive moves to provide cognitive, emotional, or cultural support to students. However, this study does not provide teachers with a strategy selection plan tailored to specific discourse contexts, such as different types of student responses. This limitation needs further research, which focuses on the analysis of teacher-student dialogue sequences, exploring the selection and outcomes of the teacher's discourse strategies in different dialogue contexts.

Conclusion and Implications

Collectively, this research demonstrates a significant correlation between teachers' discourse strategies and the quality of students' scientific discourse within whole-class teaching. High cognitive demand questions posed by teachers can trigger the production of students' scientific discourse, and the facilitating role of teachers' discursive moves cannot be overlooked. As primary participants in classroom dialogue, science teachers need to understand the differences in the quality of students' scientific discourse and the crucial role of teacher questions and discursive moves. To effectively promote students' scientific discourse production, teachers should employ questions of high cognitive demand and flexibly utilize their discursive moves. This study focuses on whole-class teaching with large class sizes, which is overlooked by most research. Additionally, this study provides indicators of teachers' discourse strategies and their functions in fostering students' scientific discourse, which can help science teachers understand and reflect on classroom discourse and improve their discourse.

The scope of this study is confined to a single science classroom, involving one teacher and 50 students, thereby limiting its potential for broader generalization. However, through reasonable purposive sampling and linking results with existing research, this study showed that these findings do not significantly deviate. Furthermore, as this study was conducted in China, there is a clear need for expanded research to further explore the correlation between teachers' discourse and the scientific quality of students' discourse in whole-class teaching across varied contexts.

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Declaration of Interest

The authors declare no conflict of interest.

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