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ORIGINAL RESEARCH

Research on the correlation between teacher classroom questioning types and student thinking development from the perspective of discourse analysis

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Abstract
Discourse analysis, as a mainstream research method in classroom teaching, has gained widespread attention in education. Educators believe that children's thinking development requires support from interactive discourse. In this study, four primary school mathematics classes were segmented based on the form, frequency, content, and purpose of teacher-student interactions. A total of 73 dialogue segments were selected for coding, resulting in 338 codes. The coding process was based on the turn of talk and assigned corresponding coding numbers to the content of teacher-student discourse in the fragments according to the Bloom-Turney teaching questioning code list and the Hierarchical Framework of Student Thinking Level based on Biggs-Collis Structure of the observed learning outcome. The results show that Knowledge level question (Q1), Understanding level question (Q2), Application level question (Q3), Synthesis level question (Q5), and Evaluation level question (Q6) are related to students' low-level thinking. The questions of Analysis level (Q4), Synthesis level (Q5), and Evaluation level (Q6) are related to students' high-level thinking. We found that there are variety of interactive structures between teachers and students in the question and answer session, among which three interaction structures show significant performance, namely Q2 → M (Multiple-point structural level) → Q4 → C (Correlational structural level), Q3 → M → Q4 → C, Q3 → M → Q6 → A (Abstract-extension level), these structures can show how teachers timely adjust the types of questions according to students' answers to improve students' thinking level.

Keywords High-order thinking · Questioning types · Lag Sequential Analysis (LSA) · Teacher-student dialogue

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Introduction

Classroom discourse, as the most fundamental carrier of classroom teaching, has been widely valued by researchers. Classroom discourse refers to the form of conversation and its educational function in the classroom, and it is a key topic in educational science (Sedova et al., 2016). Classroom discourse is highly complex, and it is also the core of all classroom interactions (Walsh, 2013). Classroom questioning refers to the process of leading students to discover a series of logical conclusions by eliciting their understanding of a particular topic (Vale, 2013). As an important component of classroom discourse, questioning is considered one of the basic ways to stimulate students' thinking and learning (Aschner, 1961). In classroom teaching, teacher questioning can encourage students to think and understand concepts, phenomena, and values; check students' understanding, knowledge, and skills; focus attention on the next teaching point; recall and reinforce previously learned knowledge; manage classroom order; and provide students with opportunities to express their ideas (Wragg, 1989).

In today's information age, thinking ability is regarded as crucial for learners to cope with a rapidly changing world (Cotton, 1991). Therefore, how schools and teachers cultivate students' thinking and students' thinking development has long been of interest to educational researchers. Researchers have defined thinking and described the types of thinking from their research perspectives. Essentially, thinking is considered a cognitive process and an act of acquiring knowledge (Presseisen, 1984). Researchers have different views on the classification of thinking, and these different views can be classified according to different research perspectives: widely researched types of thinking, such as critical thinking, creative thinking, and thinking related to understanding and actively using knowledge; specialized types of thinking, such as decision-making, solving daily problems, and solving mathematical and scientific problems (Swartz & Perkins, 2016). It should be noted that high-order thinking skills are also one of the key research topics for educational researchers at present. High-order thinking skills are the ability to creatively and innovatively apply knowledge or methods to solve problems (Lewis & Smith, 1993). The skills are often categorized as problem-solving, creative, and critical thinking (Hwang et al., 2017; Scherer & Tiemann, 2014). Cultivating high-order thinking has become a teaching goal in multiple countries. Singapore's 21st Century Competencies and Student Outcomes Framework emphasizes the development of critical thinking, creativity, and problem-solving skills (Ministry of Education, 2023). Canada's 21st Century Learning Skills in Ontario states that students should develop critical thinking, creativity, and self-directed learning skills, and describes in detail the strategies and methods for developing these skills (Ontario Ministry of Education, 2016). The Australian Curriculum: General Capabilities describes in detail how higher-order thinking skills are developed through curriculum and instruction (Australian Curriculum Authority, 2013).

Vygotsky (1978) believed that there is a strong connection between thinking and language, and they pointed out the central role of language in the development of higher psychological functions. Bruner and Bruner (1990) also believed that children's thinking development relies on dialogue with those around them. From the definition of classroom questioning, questioning to some extent can influence students' thinking development. However, some studies have shown that teachers find it difficult to ask questions that focus on or expand students' thinking in the classroom (Teuscher et al., 2016). Yet, the current research in this area is not sufficient in terms of quantity or quality. Therefore, there is still a need for a lot of classroom observation and teaching research to help teachers become aware of and improve existing problems. To this end, this study further explores the relationship between questioning types in the classroom and students' thinking levels, as well as how teachers can influence students' thinking development through questioning. This will help to explore the underlying mechanisms between classroom questioning and student thinking development and promote reforms in classroom teaching practices.

Literature review

Classroom discourse analysis

Existing studies on classroom discourse analysis have revealed various issues in teacher-student interactions in the classroom, demonstrating the necessity of analyzing classroom discourse. Rymes (2015) proposes that classroom discourse analysis is a research method that observes language use in the classroom context to understand how context and conversation interact with each other, aiming to improve future classroom interactions and have a positive impact on social outcomes beyond the classroom. Discourse research has become an important topic in educational research since the 1960s and has achieved significant research outcomes. Mehan (1980) further clarified the IRF (Initiation-Response-Feedback) classroom discourse structure as the IRE (Initiation-Response-Evaluation) structure, which makes the complex interaction in the classroom clearer and provides new perspectives and ideas for related empirical research. There is also a simplified version of the IRE structure, the IR (Initiation-Response) structure, which only includes initiation and response (Sinclair & Coulthard, 2013). Salleh et al. (2022) have found that the teacher's power, mastery of teaching language, and good classroom interaction impact whether effective learning can be achieved in the classroom. However, teachers do not always use appropriate prompts and questioning techniques that promote critical thinking and deep learning. Therefore, it is necessary to cultivate teachers' awareness of the use of classroom discourse and its impact on learning. In addition to focusing on teachers' teaching discourse, many studies have also focused on teacher-student discourse interactions, revealing that power dynamics or emotional factors can influence teacher-student discourse interactions to some extent. For example, in classroom interactions, students tend to interact more with peers than with teachers (Hidayati et al., 2022). This also requires teachers to use interactive strategies to improve student participation.

Analysis of teacher-student discourse should pay attention to the coherence of observation. Empirical research on teacher discourse, student discourse, or teacher-student interaction discourse tends to separate teacher and student discourse for quantitative or qualitative analysis. The introduction of the lag sequential analysis (LSA) into the field of education research has improved this problem. LSA is mainly used to analyze the probability of one behavior occurring with another behavior in the observed activity, as well as whether this behavior sequence has statistical significance (Sackett, 1978). Unlike simple frequency statistics, lag sequential analysis focuses on the correlation between different behaviors of teachers and students during a classroom observation.

The development of empirical research on classroom discourse is accompanied by the emergence of various tools for analyzing classroom interactions, which assist in research on classroom discourse. Flanders proposed the Flanders Interaction Analysis System (FIAS) in the 1960s. The FIAS coding system divides classroom interactions into three types of behavior: teacher language, student language, and silence or confusion, which are further divided into 10 interactive behavior codes (Flanders, 1963). In addition, The Teacher Scheme for Educational Dialogue Analysis (T-SEDA) is also a tool for analyzing classroom discourse. T-SEDA can help educators investigate classroom discourse interactions and make desired changes to promote high-quality dialogues (Vrikki et al., 2019). The T-SEDA dialogue coding framework includes multiple observable indicators, such as inviting the development of ideas, supplementing and developing ideas, questioning, inviting reasoning and argumentation, engaging in explicit reasoning and argumentation, coordinating and agreeing on ideas, connecting, reflecting on dialogues or activities, seeking directions for dialogues or activities, and expressing or requesting ideas from others.

Study of teacher questioning and its types

Teacher questioning is a classroom observation dimension that has been recognized and valued by numerous classroom teaching researchers. Teacher questioning is defined by Cotton (1991) as guiding cues that convey content elements or stimulate learning and guide students on what to do and how to do it. Since Socrates first demonstrated the use of questioning, questioning has become a tool for people to pursue correct understanding and action (Dillon, 2004). For classroom teaching, questioning also plays an important role. Flanders listed questioning as one of the main dimensions of studying teacher behavior in the Flanders Interaction System (Flanders, 1963). Recent empirical studies have also found the importance of teacher questioning in classroom interaction: teaching with questioning is more effective than teaching without questioning (Olaniran & Akorede, 2018). The types of questions used by teachers can effectively engage learners in classroom interaction (Saswati, 2022), while also encouraging sustained and lengthy student expression (Fadilah & Zainil, 2020).

There have been various classification systems proposed for classroom question types, most of which are from the perspective of student cognitive development. Among them, the more famous ones include: Adams (1980) categorized question types into memory-based questions, logical reasoning questions, evaluative questions, clarifying questions, associative questions, and neutral questions. Aschner (1961) categorized question types into rote memory, reasoning, creative thinking, and evaluative questions. Bloom's taxonomy categorizes question types into Knowledge-based questions, Comprehension-based questions, Application-based questions, Analysis-based questions, Evaluative questions, and Creative questions (Bloom et al., 1956). Turney constructed the "Bloom-Turney teaching questioning Code List" based on the basic ideas of Bloom's cognitive objective classification (Turney, 1973). Most of the above classifications of question types are from the perspective of student cognitive development, ignoring the importance of order and follow-up questions. Observations of teachers' classroom questioning should focus on what types of questions occur at a given period rather than what kinds of questions are asked at a given point in time.

Definition of higher-order thinking skills and its evaluation

There are various perspectives on the definition of higher-order thinking skills, but some commonalities can be found: they are built on lower-order thinking skills, involve analyzing and evaluating old knowledge, and creatively applying it to new situations. Researchers have different views on the definition of higher-order thinking skills. Conklin (2011) argues that higher-order thinking includes critical and creative thinking. Islamiaty et al.

(2020), on the other hand, believe that it is synonymous with critical thinking. Lewis and Smith (1993) propose that differentiates higher-order thinking from critical thinking, stating that it occurs when a person retrieves stored information from memory and then reorganizes, expands, or links that information to achieve a specific goal. Additionally, some researchers define higher-order thinking from the perspective of distinguishing between high and low levels of thinking. For example, Thompson (2008) believes that high-level thinking is characterized by the diversity, complexity, and irregularity of problem-solving solutions, while low-level thinking is characterized by knowledge application and information retrieval. From the definitions provided by these researchers, we can conclude that higher-order thinking is the ability to analyze, evaluate, and creatively apply previously acquired knowledge to new situations, built on lower-order thinking skills.

Evaluation of high-order thinking skills can be divided into research that emphasizes speculation, research that emphasizes quantitative analysis, and research that emphasizes qualitative analysis. High-order thinking skills not only improve academic performance but also cultivate lifelong learners (Conklin, 2011). Existing higher-order thinking skills research can be categorized into three types of Evaluation methods: speculation-based research, quantitative research, and qualitative research. Speculation-based research mainly explores methods of evaluating high-order thinking from the summary of various theoretical experiences (Brookhart, 2010). Quantitative research is devoted to evaluating students' thinking development by developing various test questions. For example, Othman et al. (2018) view creativity, evaluation, analysis, and application as four levels of thinking, and evaluate students' thinking development level through semi-structured interviews. In qualitative research, there are also various research systems and frameworks used to analyze students' thinking development. Bloom's taxonomy's purpose is to promote higher-level thinking modes in education, such as analysis and evaluation, rather than just teaching students to memorize facts (Collins, 2014).

In summary, previous research has emphasized the importance of classroom questioning for students' thinking and development from both a speculative and empirical perspective, using a variety of theoretical and methodological approaches. Questioning is an effective way to stimulate student interaction, thinking, and learning. However, research on the relationship between different types of teacher questioning and student thinking development is still in its early stages, as is the study of the impact of questioning in elementary school classrooms on student high-order thinking development. Based on the above analysis, this study involves two research questions:

1. What is the relationship between the different types of questions asked by teachers and the different thinking levels of students?
2. How can teachers coordinate different types of questions in the teaching process to improve students' thinking levels?

According to Bloom's taxonomy, students' ability to analyze, synthesize, and evaluate is associated with higher-order thinking (Aziz & Kharis, 2021). Biggs-Collis Structure of the observed learning outcome (SOLO) is divided into five levels: Prior structural, Single-point structural, Multiple-point structural, Correlational structural, and Abstract-extension. Among these, Correlational structural and Abstract-extension belong to higher-order thinking levels (Biggs & Collis, 2014).

Gall (1970) argues that follow-up questions to students' initial answers in classroom teaching have a great impact on their learning. Shaver (1964) emphasizes this point, believing that teachers should ask appropriate follow-up questions after students state their opinions to promote in-depth exploration. Higher-order thinking occurs when connections are made between new and previous knowledge and this combination of knowledge is applied to solve complex problems (Misrom et al., 2020; Yee et al., 2015). Based on the above analysis, the following research hypotheses are proposed:

1. High-level thinking questions (analyze, synthesize, and evaluate level questions) are related to high-level thinking (Correlational structural and Abstract-extension level). Low-level thinking questions (Knowledge, Comprehension, and Application level questions) are related to low-level thinking (Prior structural, Single-point structural, and Multiple-point structural level).
2. Teachers ask questions that help students actively retrieve a variety of relevant knowledge, and then follow up with more challenging questions based on the student's answers to promote their thinking development.

Method

Research sample

This study selects four recorded lessons from the sixth-grade textbook of elementary school mathematics, including integer division by fractions, the surface area of cylinders, selection of statistical graphs, and saving water resources, as research samples, with sample coding N1, N2, N3, and N4 (it is worth noting that the "N" comes from the first letter of the word "number"), respectively. These samples include four teachers and 136 students. The four teachers are all excellent teachers with more than 10 years of teaching experience, and their classroom teaching won the top award in China's national high-quality class selection competition. Therefore, their classroom teaching can represent the best level in the country. Students in the sample are all in the sixth grade of primary school, with an average age of 12 years old, and have certain advantages in thinking development compared with primary school students in other grades. Detailed information on the lessons is shown in Table 1 below.

Table 1 Lesson details table

Coding	Topic case	Grade level	Total number of people	City
N1	Division of integers by fractions	Grade 6	37	Peking
N2	The surface area of the cylinder	Grade 6	25	Shanghai
N3	Choosing statistical graphs	Grade 6	41	Chengdu
N4	Saving water resources	Grade 6	37	Nanjing

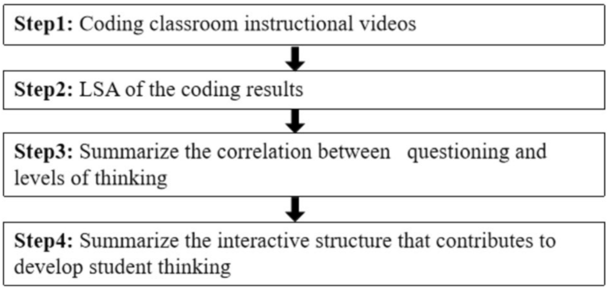

Fig. 1 The procedure of the study

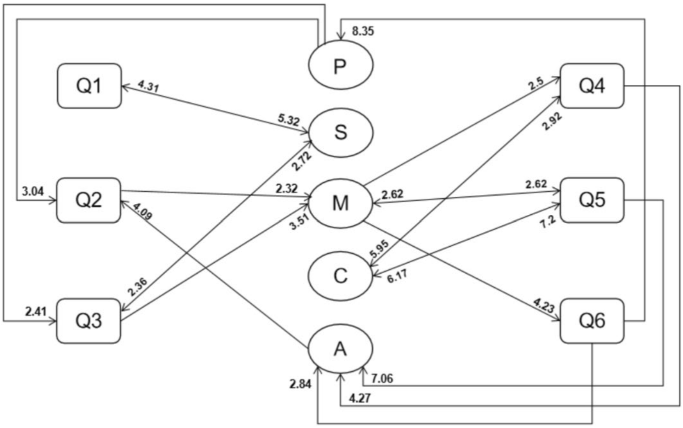

Fig. 2 Behavior transition sequence diagram

Research procedure

The study was divided into four steps (see Fig. 1). In the first step, the classroom teaching video is coded. In the second step, the Lag sequence analysis method (LSA) is used to process the coding results, obtain the Z-score table, and draw the Behavior transition sequence diagram (see Fig. 2) based on the Z-score table (see Table 4). The third step is to summarize the correlation between questioning and levels of thinking on the. To observe the relationship between question types and thinking levels more directly, this study draws the Correlation graph between question types and thinking levels (see Fig. 3) based on the Behavior transition sequence diagram (see Fig. 2). The role of this section is to observe which types of questioning are associated with what level of thinking the student has. In the fourth step, based on the Behavior transition sequence diagram (see Fig. 2) and combining the content of teacher-student dialogue in classroom teaching, the interactive structure that contributes to developing students' thinking is summarized (see Table 5), and the promotion effect of teachers' questioning on students' thinking development is discussed. The role of this part is to observe how different types of questioning coordinate with each other, to promote the development of students' thinking.

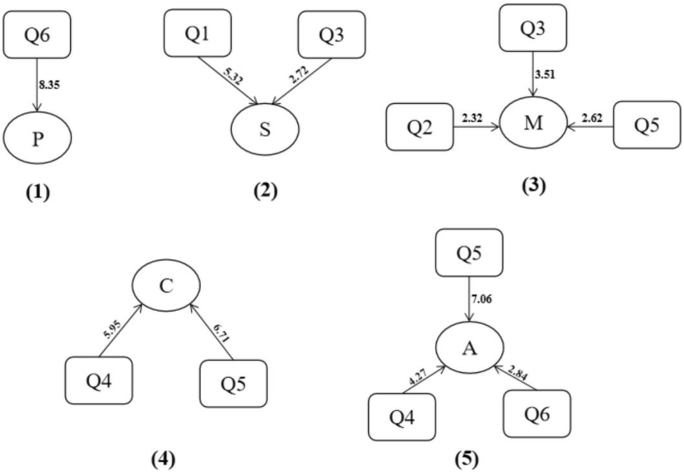

Fig. 3 Correlation graph between question types and thinking levels

Coding procedures

In this study, we segmented four classroom recordings into dialogue fragments based on the forms, frequencies, contents, and purposes of teacher-student interactions. We ultimately selected 73 dialogue fragments for coding, resulting in a total of 338 codes. In each dialogue fragment, there were teacher questions and one or more student answers, but no other types of teacher speech (such as lectures, instructions, praise, or criticism). During the coding process, codes were assigned to the content of teacher-student speech in each dialogue fragment, using the Bloom-Turney teaching questioning code list (see Table 2) and the Hierarchical Framework of Student Thinking Levels Based on SOLO Classification Evaluation Theory (see Table 3). Speech from each speaker, from initiation to conclusion, was considered one turn. Coding was done independently by two researchers. Before formal coding, the two coders were familiarized with the coding framework and underwent coding training. The Kappa reliability of the two coders at the end of formal coding was $0.81 > 0.8$, indicating high consistency between the coding results of the two coders.

Bloom-Turney teaching questioning code list is reconstructed by American educator Turney according to the basic thought of Bloom's taxonomy of teaching objectives. The first three indicators of the Bloom-Turney teaching questioning Code List belong to low-level thinking questions, and the last three belong to high-level thinking questions (Turney, 1973). Based on the Bloom-Turney teaching questioning Code List this study assigned a code name to each indicator and formed the Bloom-Turney teaching questioning Code List for observing and coding the teacher's questioning behavior in the classroom.

SOLO classification Evaluation theory is a student academic assessment method created by educational psychologist John Biggs. Biggs and Collis (2014) proposed that the thinking classification structure is a hierarchical model that goes from simple to complex and from low to high, with five levels: Prior structural, Single-point structural, Multi-point structural, Correlational structural, and Abstract extension. In this study, based on the original SOLO classification framework, the descriptive content of each indicator in the framework was further explained through multiple classroom observations and related literature research (Lewis & Smith, 1993) to facilitate more accurate coding of classroom

Table 2 Bloom-Turney teaching questioning code list

	Question type	Coding	Description	Keywords
Low-level thinking questions	Knowledge (Recall) level question	Q1	These questions are used to determine whether students have memorized previous learning, such as definitions, formulas, theorems, specific facts, and concepts	Who, what, where, when
	Comprehension level question	Q2	These questions are used to help students organize their learning, clarify their meanings, and require them to use their own words to describe what they have learned. They can compare and contrast knowledge or events and transform knowledge from one form to another	How to understand, based on what, why, how, in your own words
	Application level question	Q3	These questions are used to encourage and help students apply the knowledge they have learned to solve problems. They require students to apply certain rules or theories to certain problems, and classify and select problems to determine the correct answer	Apply, use, classify, select, give an example

Table 2 (continued)

	Question type	Coding	Description	Keywords
High-level thinking questions	Analysis level question	Q4	These questions can be used to analyze the structure and factors of knowledge and clarify the relationships between things or the causes and effects of events. They require critical thinking, and the ability to analyze data to determine causes and make inferences	What factors, conclude, prove, and analyze
	Synthesis level question	Q5	These questions can be used to help students combine their learned knowledge in a new or creative way, forming a new relationship. Such questions are often used to develop students' creative abilities. They examine the overall understanding of students on a topic or content, requiring students to anticipate and creatively solve problems	Create, anticipate, if…then…, summarize, conclude
	Evaluation level question	Q6	These questions can be used to help students judge the value of materials based on certain standards. They require students to judge and select concepts, values, problem-solving methods, or ethical behaviors, and to express their opinions	Judge, evaluate, what is your Opinion

Table 3 Hierarchical framework of students' thinking level

	Thinking level	code	description
Low-level thinking	Prior structural level	P	Student extracts information incorrectly, have a confused thinking process; mechanically repeat other people's views; give answers that are completely wrong or unrelated to the question; take too long to think, and ultimately cannot provide an answer
	Single-point structural level	S	The student understands the requirements of the question, reviews learned formulas, and concepts, or solves problems using learned formulas, principles, or concepts in similar problem contexts; incorporates their ideas based on the views of others and elaborates further; answers questions using traditional thinking or common sense
	Multiple-point structural level	M	Students can actively extract some relevant information but do not consider the correlation between information; can find the correlation between information under the guidance of the teacher; can use multiple methods or perspectives to solve problems
High-level thinking	Correlational structural level	C	Students can actively extract a considerable amount of relevant information, conduct systematic analysis and expression; have an overall grasp of the requirements of the question, and can actively integrate all relevant knowledge to solve problems
	Abstract-extension level	A	Proposes answer methods, perspectives, or thinking beyond standard answers; further summarizes the obtained correlative structures and applies them to new fields

interactions, as shown in Table 3. Based on this framework, the thinking development level presented in the content of students' discourse was coded, that is, when a teacher posed a question in class, we could see which level of thinking the students' answers belonged to and assign a certain code to that response.

Data analysis procedure

In this study, we mainly use the Lag sequence analysis method to obtain the significant behavior sequence in the classroom, then observe the internal relationship between teacher questioning and students' thinking development, and explore how teachers can improve students' thinking levels through questioning.

When using lag sequential analysis, the GSEQ (Generalized Sequential Querier) software was used for data processing. GSEQ is an interactive sequence analysis software that can perform various simple data statistics, including frequency, rate, duration, and percentage of behavior (Bakeman & Quera, 1995). It can also perform statistics on the sequence of interactive behaviors, including joint frequency, adjusted residuals, and chi-square. Because the GSEQ software does not support direct coding of classroom recordings, the coded results were entered into an SDS file created in GSEQ during the research process. Then the SDS files were saved in MDS files format on the computer, and the Z-score table of behavior transitions (see Table 4) were obtained by running it.

In the table, each row represents the initiating behavior, each column represents the accompanying behavior, and the value at the intersection of the row and column is the residual value of the two behaviors. The Z-score table of behavior transitions is generated based on the Behavior conversion frequency table and represents the residual parameter (z). When the z-value in the table is greater than 1.96, it indicates that the behavior sequence has statistical significance.

To more intuitively observe the correlation between teacher's question type and students' thinking level, as well as how teacher question types promote students' thinking development, this study also draws the Behavior sequence diagram (see Fig. 2) based on the significant behavior sequence in the Z-score table (see Table 4).

Table 4 Z-score table of behavior transitions

	Q1	Q2	Q3	Q4	Q5	Q6	P	S	M	C	A
Q1	0	− 1.92	0.25	− 2.14	− 2.08	− 1.47	− 1.3	5.32*	− 1.22	− 1.61	− 1.69
Q2	− 2.39	0	− 1.84	0.16	− 1.42	0.13	1.29	1.12	2.32*	1.65	− 0.15
Q3	− 2.7	− 1.18	0	− 0.53	− 1.34	− 0.95	0.58	2.72*	3.51*	− 0.59	− 1.09
Q4	− 2.14	− 1.46	− 1.38	0	− 1.06	− 0.75	0.12	− 0.86	1.35	5.95*	4.27*
Q5	− 2.08	− 1.42	− 1.34	− 1.06	0	− 0.73	− 0.97	− 2.03	2.62*	6.17*	7.06*
Q6	− 1.54	− 1.05	− 0.99	− 0.79	− 0.77	0	8.35*	− 0.75	− 0.7	− 0.81	2.84*
P	1.31	3.04*	2.41*	− 1	0.18	0.9	0	− 2.7	− 0.88	− 1.03	− 0.79
S	4.31*	− 0.24	2.36*	0	− 0.25	0.06	− 1.76	0	− 3.07	− 3.14	− 2.74
M	0.13	1.42	− 1.22	2.5*	2.62*	4.23*	0.37	− 3.07	0	− 0.99	− 0.76
C	0.15	1.65	− 1.42	2.92*	7.2*	0.65	− 1.03	− 3.56	− 0.99	0	− 0.89
A	− 0.07	4.09*	0.05	1.84	− 0.8	− 0.57	− 0.76	− 2.07	0.76	− 0.85	0

*z > 1.96

In the diagram, each arrow points to the accompanying behavior after the initiated behavior, and the value of the line is the Z-score in the residual table. The larger the z value, the higher the significance of the corresponding behavior sequence.

Research Results

The correlation between teacher's question type and students' thinking level

This study draws the Correlation graph between question types and thinking levels (see Fig. 3) based on the Behavior sequence diagram (see Fig. 2) to observe the relationship between question types and thinking levels.

It can be observed that when teachers ask questions at the Evaluation-level questions (Q6), students' answers usually correspond to the Prior structural level (P). The following is a dialogue fragment that exemplifies this type of discourse sequence structure in a real classroom situation.

1 Q6 → P sequence:

> (At this point, students have not yet learned knowledge about the surface area of the cylinder.)
> T: There are two different cylindrical water bottle designs, which do you think might be more economical in terms of material use, and why? [Q6].
> S: The higher the height of the water bottle, the more material will be used, so use the shorter bottle. [P].

It can be seen that when the teacher's questions go beyond the original cognitive scope of students, students may not be able to extract effective information and answer the questions incorrectly.

When teachers ask questions at the Knowledge level (Q1) and Application level (Q3), students' answers usually correspond to the Single-point structure level (S), among them, the correlation between (Q1) and (S) is greater than that between (Q3) and (S). The following is a dialogue fragment that exemplifies this type of discourse sequence structure in a real classroom situation.

1. Q1 → S sequence:

> T: Do you remember the feature of a bar chart? [Q1].
> S: Can indicate the size of the quantity clearly, easy to compare. [S]

2. Q3 → S sequence:

> T: What other examples can you give that can be solved with bar charts? [Q3]
> S: The number of boys and girls in a class can be counted using a bar chart. [S]

When teachers ask questions at the Comprehension level (Q2), Application level (Q3), and Synthesis level (Q5), students' answers usually correspond to the Multiple-point structure level (M), among them, (Q3) have the strongest correlation with (M), followed by (Q5) and (Q2). The above analysis results show that questions at the Knowledge level (Q1), Comprehension level (Q2), Application level (Q3), Synthesis level (Q5), and Evaluation-level (Q6) are related to low-level thinking in students. The following is a dialogue fragment that exemplifies this type of discourse sequence structure in a real classroom situation.

1. Q2 → M sequence:

T: How did he get to the step of integer operation? [Q2]
S: He split the fraction and turned 3/4 into 3 divided by 4. [M]

2. Q3 → M sequence:

T: Before class, I asked you all to simulate investigating the water leakage situation of a faucet for 1 minute. Based on the data that you have collected, which statistical methods would you choose to organize this data? [Q3]
S: We can use statistical tables or graphs. [M]

3. Q5 → M sequence:

T: Are there any other new approaches? [Q5]
S: You can cut the cylinder; when you unfold it, you have a rectangle and two circles. [M]

When observing the distribution of the student's Correlational structure level (C), it can be found that the performance of (C) is significant when teachers use Analysis level question (Q4) and Synthesis level question (Q5) in the classroom questioning, among them, the correlation between (Q5) and (C) is greater than that between (Q3) and (S). The following is a dialogue fragment that exemplifies this type of discourse sequence structure in a real classroom situation.

1. Q4 → C sequence:

T: If you choose to use a graph, analyze your group's survey data and tell me which type of graph is suitable and why you chose to use it. [Q4]
S: We can use a bar chart or a histogram to present the data. A bar chart can be used to compare the amount of leakage at different periods, while a histogram can be used to show the distribution of leakage. [C]

2. Q5 → C sequence:

T: If you want a fan chart, how do you think it should be drawn? [Q5]
S: If we use a fan chart, we can use different colors to represent different objects, we can observe the fan area, and we can also observe the data of each object, in this way, we can compare the use of different objects. [C]

When observing the distribution of the student's Abstract extension level (A), it can be found that the performance of (A) is significant when teachers use Analysis-level question (Q4), Synthesis-level question (Q5), and Evaluation-level question (Q6) in questioning, among them, (Q5) has the strongest correlation with (A), followed by (Q4) and (Q6). The above analysis results show that questions in the analysis (Q4), synthesis (Q5), and Evaluation (Q6) question are related to students' high-level thinking. The following is a dialogue fragment that exemplifies this type of discourse sequence structure in a real classroom situation.

1. Q4 → A sequence:

T: What factors prevented him from continuing the calculation?
S: He didn't see by looking at the expansion that he should add the side area and the two lows.

2. Q5 → A sequence:

T: If you want a fan chart, how do you think it should be drawn? [Q5]
S: If we use a fan chart, we can use different colors to represent different objects, we can observe the fan area, and we can also observe the data of each object. In this way we can compare the use of different objects. [A]

3. Q6 → A sequence:

T: Based on the pie chart above, try to evaluate what kind of person he might be. [Q6]
S: According to the pie chart, social media has the highest proportion, indicating that he is an expressive person. Then, reading software is the next highest, indicating that he loves to read, so I think he might be a teacher. In general, I think he is someone who likes to play with their phone. [A]

The promotion of teacher questioning on students' thinking levels

By observing the Behavior transition sequence diagram (see Fig. 2) and the actual classroom dialogue content, we found that there were various interactive structures in the Q&A section between teachers and students, and three types of interactive behaviors were significant, these structures and their sources are shown in Table 5.

1. Q2 → M → Q4 → C structure.

Table 5 Discourse interaction structure sample coding table

Number	Structure	Source
1	Q2 → M → Q4 → C	From N1 case
2	Q3 → M → Q4 → C	From N3 case
3	Q3 → M → Q6 → A	From N4 case

After the teacher posed a question about the level of understanding, the student's answers reached the level of Multiple-point structure. When the teacher followed up with a question about the level of analysis, the student's answer reached the level of Correlational structure. The following is a dialogue fragment that exemplifies this type of discourse interaction structure in a real classroom situation:

T: How did he get to the step of integer operation? [Q2]
S: He split the fraction and turned 3/4 into 3 divided by 4. [M]

T: Why did he do that? Think about which method he learned with us before, and how he solved this problem. [Q4]
S: He used the multiplication and division rule we learned before. After he opened the parentheses, the division sign became a multiplication sign. [C]

From the perspective of students' thinking development, when students move from the level of Multiple-point structure to the level of Correlational structure, they establish connections between the previously extracted information, which leads to a deeper and more comprehensive understanding of the problem. In the above fragment, when the teacher asked the student how to get from fraction operation to integer operation, the student's initial response only saw the superficial information "splitting the fraction 3/4 into 3 ÷ 4". Although the student knew the multiplication and division rules, he could not connect the problem at hand with the knowledge in their mind, resulting in an inaccurate and incomplete answer to the teacher's question. Through the teacher's guidance, the students established connections between old and new knowledge, and their thinking developed to the level of relational structure.

From the perspective of teacher questioning strategies, the teacher first posed a question at the level of Comprehension, that is, how to get from fraction operation to integer operation, guiding the student to conduct basic thinking and response. Questions at the level of Comprehension can help students transform some knowledge from one form to another. When students answer these questions, they extract some effective information to solve the problem but need to clarify the relationship between previously learned knowledge and the problem at hand and construct new knowledge. At this point, the teacher's further guidance is particularly important. Therefore, after the student's response, the teacher followed up with a question at the level of analysis, that is, why do we need to do that, and how do we solve the problem? This question requires students to analyze and understand the entire problem at a deeper level, thus promoting further development of their thinking.

2. Q3 → M → Q4 → C Structure.

When a teacher posed a question about the Application level, the student's answer reached the multi-point structure level. Following this, when the teacher further questioned the Analysis level, the student's response reached the Correlational structure level. The following dialogue fragment illustrates this kind of discourse interaction structure in a real classroom situation:

T: Before class, I asked you all to simulate investigating the water leakage situation of a faucet for one minute. Based on the data that you have collected, which statistical methods would you choose to organize this data? [Q3]
S: We can use statistical tables or graphs. [M]

T: If you choose to use a graph, analyze your group's survey data and tell me which type of graph is suitable and why you chose to use it. [Q4]
S: We can use a bar chart or a histogram to present the data. A bar chart can be used to compare the amount of leakage at different periods, while a histogram can be used to show the distribution of leakage. [C]

From the perspective of teacher questioning strategies, the teacher first posed a question about the Application level, guiding the students to think about which statistical methods to use to organize the data. An Application-level question requires students to apply certain theories to certain problems, and classify and select the problems to determine the correct answers. After the student responded, the teacher further questioned at the Analysis level, guiding the students to think about how to choose the appropriate statistical graph. Analysis-level questions can guide students to analyze the structure and factors of knowledge and clarify the relationships between things. This progressive questioning strategy can help stimulate student thinking, guide students to think deeply about problems, and gradually improve their thinking skills.

From the perspective of student thinking development, the student's response gradually rose from the Multiple-point structure level to the Correlational structure level. The student first answered the Application-level question, proposing that statistical tables or graphs could be used. Then, when the teacher further questioned at the Analysis level, the student's answers not only considered which statistical graph to use but also explained why they chose to use it. This kind of response indicates that the student has gradually developed the ability to connect different parts of the problem, that is, the Correlational structure level. This gradually improving thinking level not only helps students better understand and apply knowledge but also enhances their creative thinking ability.

The appearance of this kind of interaction structure shows the close relationship between teacher questioning strategies and student thinking development. Teachers should adjust their questioning strategies flexibly according to the student's response situation, guiding students to gradually improve their thinking skills.

3. Q3 → M → Q6 → A Structure.

When the teacher asked a question about the Application level, the students' answers reached the Multiple-point structure level. When the teacher followed up with a question about the Evaluation level, the students' answers reached the Abstract extension level. The following is a dialogue excerpt of this discourse interaction structure that occurred in a real classroom scenario:

T: Based on the data displayed on the screen, which statistical graph would you choose to represent the data and why? [Q3]
S: We chose a pie chart. It shows the size of each part. [M]

T: Based on the pie chart above, try to evaluate what kind of person he might be. [Q6]
S: According to the pie chart, social media has the highest proportion, indicating that he is an expressive person. Then, reading software is the next highest, indicating that he loves to read, so I think he might be a teacher. In general, I think he is someone who likes to play with their phone. [A]

Compared with (1) and (2), it can be observed from the sequence structure of (3) that the difficulty level of the teacher's questions is different, and the level of thinking that students can reach is also different.

From the perspective of the teacher's questioning strategy, the teacher's questions are aimed at actual data, rather than simply requiring students to memorize and recite knowledge points. The teacher first asks a question about the Application level, requiring students to choose an appropriate statistical graph from the data, guiding students to start with specific problems, and thus reaching the Multiple-point structure level. Then the teacher follows up with a question about the Evaluation level, asking students to speculate possible character traits and identities from the data, guiding students to think about deeper knowledge, and finally reaching the abstract extension level. The teacher's questioning strategy helps guide students to think about deeper knowledge and issues, helping them better understand and apply knowledge.

From the perspective of students' thinking development, students first analyze data from multiple aspects, choose an appropriate statistical graph, and reach the Multiple-point structure level of thinking. Then, based on the data, students speculate on possible character traits and identities and engage in logical reasoning and judgment, reaching the abstract extension level. This gradually increasing level of thinking helps students better understand problems and knowledge points, and better apply them in subsequent learning and application.

It can be seen that all three types of interaction structures are beneficial to students' thinking development. First, immediately following up with high-level thinking questions after low-level thinking questions is effective and can assist students in transitioning from low-level to high-level thinking. Second, comparing the three interaction structures, the results show that the Multiple-point structure level (M) is an important node in students' thinking development from low to high level. This indicates that students can extract some valid information in classroom teaching, but are unable to consider the relationships between information. In such cases, teachers need to help students find the relationship between information or solve problems from multiple perspectives and methods through questioning.

Discussion

The purpose of this study was to observe the intrinsic associations between teachers' different questioning types and students' different levels of thinking by coding classroom instruction and to explore how teachers can coordinate questioning types to promote students' thinking development. Research finds that Knowledge level question (Q1), Comprehension level question (Q2), Application level question (Q3), Synthesis level question (Q5), and Evaluation level question (Q6) are related to students' low-level thinking. The questions of Analysis level (Q4), Synthesis level (Q5), and Evaluation level (Q6) are related to students' high-level thinking. We found that there are A variety of interactive structures between teachers and students in the question and answer session, among which three interaction structures show significant performance, namely Q2→M→Q4→C, Q3→M→Q4→C, Q3→M→Q6→A, which can show how teachers timely adjust the types of questions according to students' answers to improve students' thinking level.

In terms of the intrinsic connection between question types and each level of thinking development, the results of the study showed that high-level thinking questions were related to students' high-level thinking, and low-level thinking questions were related to students' low-level thinking, which confirms previous hypotheses. This indicates that appropriate questioning strategies are effective in improving students' higher-order thinking abilities (Rahayu & Utaminingsih, 2016). However, unlike the previous hypotheses, the findings showed that high-level thinking questions were sometimes associated with students' low-level thinking, for example, Synthesis level question and Evaluation level question are related with low level thinking. This is different from what previous studies have found that students' ability to analyze, synthesize, and evaluate is associated with higher-order thinking (Aziz & Kharis, 2021). One possible explanation is that due to the different cognitive levels of the study participants when the teacher increased the difficulty of the questions just far beyond the existing cognitive level of a particular student, it resulted in higher-order questions that did not elicit higher-order thinking, but instead led to cognitive dissonance. Therefore, teachers when attempting to include more higher order questions as part of the assessments, may face the situation that the questions raised are far beyond the current cognitive level of students, resulting in students not only failing to think further but giving wrong answers, such as Q6→P sequence in the research results. Therefore, this requires teachers to be able to identify and adapt to the different needs of students and provide personalized support and guidance, which undoubtedly brings challenges to teachers' lesson preparation and teaching.

In terms of the level of teachers' questioning in promoting students' thinking development, the research results show that three significant interactive structures in the classroom teaching process contribute to the development of students' thinking. As in previous studies, teachers present information and allow exploration through guided questions to enhance learning and promote students' thinking skills (Chin, 2007; Scott, 1998). The research also found that in these three interactive structures that are conducive to promoting the development of students' thinking, the teacher's first question made the students' thinking level reach the Multiple-point structure level (M). When the students' thinking development reached the Multiple-point structure level, the teacher increased the difficulty of the question and used high-level thinking questions, making the students' thinking development reach the high-level thinking level. It can be found that questions that help students reach multiple structural levels provide scaffolding for the generation of students' high-level thinking. The same as previous research points, questions that encourage students to activate their existing cognition can help cultivate their higher-order thinking (Aziz & Kharis, 2021). Teacher questions should help students build relationships between existing knowledge and new concepts, thereby expanding their knowledge base and helping students apply newly acquired concepts to different situations (Yip, 2004). At this time, the important factor affecting whether students can produce higher-order thinking is that teachers adjust the types of questions timely according to students' answers, such as increasing the difficulty of questions. Therefore, Teachers should adjust their questioning strategies according to students' answers (Hargreaves, 1984).

It is now widely believed that teacher-student dialogue matters as regards student outcomes (Howe et al., 2019). Our research is of great significance to teachers' dialogue teaching. Children's thinking development relies on dialogue with those around them (Bruner & Bruner, 1990). Our results show that there is a significant correlation between different types of questions and students' different levels of thinking. In the course of teaching design, teachers can refer to the results of this study to set questions and think "What kind of thinking will this question cause students?" (Vale, 2019). In addition, in the teaching process, teachers should pay attention to the Multiple-point structure level of students' thinking as an important fulcrum to develop students' thinking. In other words, they should help students activate cognition by asking questions, taking the initiative to extract all kinds of knowledge, and then promoting the development of students' higher-order thinking by asking more difficult questions.

Limitations and prospects

The interpretation of the results of this study has some limitations. Firstly, the sample size used in the study was relatively small and did not seek a large number of samples for large-scale analysis. Secondly, there are other uncontrollable factors in classroom observations, such as students' previous thinking development, which may have an impact. Finally, this study focused on groups rather than individuals and did not observe the thinking changes of each student.

Future research can consider the following three improvements. First, consider increasing the size of the sample to get a wider range of analysis results. Second, the pre-test is used to gain a basic understanding of the student's previous thinking development to better interpret the research findings. Third, future research could consider more detailed observations and analyses at the group or individual level to take a closer look at the individual attention teachers provide to students.

Conclusion

In this study, we first coded the classroom teaching videos, and then processed the coding results using the Lag sequence analysis method to obtain significant behavioral sequences between teachers and students, and then observed the internal relationship between teachers' questioning and students' thinking development, and discussed how teachers can improve students' thinking level by changing the way they ask questions. The results show that Knowledge level question (Q1), understanding level question (Q2), Application-level question (Q3), Synthesis level question (Q5), and Evaluation level question (Q6) are related to students' low-level thinking. The questions of Analysis level (Q4), Synthesis level (Q5), and Evaluation level (Q6) are related to students' higher-level thinking. We found that there are a variety of interactive structures between teachers and students in the question and answer session, among which three interaction structures show significant performance, namely Q2 → M → Q4 → C, Q3 → M → Q4 → C, Q3 → M → Q6 → A, which can show how teachers timely adjust the types of questions according to students' answers to improve students' thinking level.

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Declarations

Conflict of interest The author(s) declared the manuscript has not been published in any journal and has no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

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