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A Comparative Analysis of Teacher-Student Dialogue in Expert and Novice Teachers' Smart Classrooms for Cultivating Higher-Order Thinking

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Abstract

Higher-order thinking is a core objective of smart classrooms, with teacher-student dialogue serving as its fundamental pathway and a key area of difficulty for novice teachers' professional development. This study selected 12 smart classroom teaching videos from the China Smart Education Resource Public Service Platform as research samples. Using lag sequential analysis, the study analyzed the frequency and sequences of teacher-student dialogue in smart classrooms between novice and expert teachers. The results revealed significant differences in both the forms and patterns of teacher-student dialogue between novice and expert teachers: novice teachers exhibited relatively singular dialogue forms and patterns, whereas expert teachers demonstrated diversified dialogue forms and patterns, with dialogue patterns reflecting a complete process of smart inquiry-based learning. This research can provide a reference for teachers conducting teacher-student dialogue in smart classrooms, facilitating the optimization of smart classroom teaching models, promoting the development of students' higher-order thinking, and thereby contributing to the creation of high-quality and effective smart classrooms.

Introduction

Higher-order thinking (HOT) refers to mental activities or cognitive abilities occurring at relatively high cognitive levels, emphasizing the analysis, synthesis, evaluation, and creation of knowledge[1]. Cultivating students’ higher-order thinking is a crucial pathway for implementing subject core competencies and represents a significant goal of talent cultivation worldwide[2]. The United States includes higher-order thinking as a key component of core competencies within its 21st Century Skills Framework [3]. The World Innovation Summit also emphasizes the importance of higher-order thinking in Towards the Future: Global Experiences in 21st Century Core Competencies Education [4]. Similarly, China’s Development of Core Competencies for Chinese Students and the 21st Century Core Competencies 5C Model both highlight higher-order thinking as an essential element of core competencies [5]. However, as the classroom is the main arena for education and the primary channel for instruction, how to cultivate students' higher-order thinking within the classroom becomes a critical method for implementing core competencies. Previous studies have shown that cultivating students' higher-order thinking requires providing necessary conditions, environments, and technological support [6], with smart classrooms considered the main battleground for effectively developing students' higher-order thinking [7]. Within this context, teacher-student dialogue constitutes the core element and an important instructional method of smart classrooms[8]. In summary, exploring teacher-student dialogue in smart classrooms becomes an essential pathway for constructing high-quality and effective smart classrooms, improving smart classroom teaching quality, and promoting the development of students' higher-order thinking.

Previous research has primarily focused on the frequency, duration, and percentage of teacher-student dialogue, paying less attention to the process of occurrence and development of such dialogue—specifically, the characteristics of teacher-student dialogue sequences. Some studies have constructed analytical frameworks for teacher-student dialogue from three dimensions—interaction patterns,

knowledge construction, and classroom culture—using statistical methods to analyze the characteristics and patterns of teacher-student dialogue[9]. Leveraging artificial intelligence technology and neural network analysis models, other research has employed statistical methods to code and analyze classroom questioning, answering, and feedback[10]. Through corpus coding and analysis, studies have explored the characteristics of teacher-student dialogue that promote students' deep learning from three aspects: turn-taking features, adjacency pair features, and thematic content features[11]. Based on an analytical framework for teacher-student dialogue in elementary mathematics classrooms, some researchers have utilized statistical analysis methods to code and analyze four classroom teaching videos[12]. Analyzing the sequential characteristics of teacher-student dialogue in smart classrooms facilitates the exploration of underlying patterns and reflects the developmental pathways of students' thinking within such dialogue.

Expert teachers possess profound expertise in subject teaching, student development, and disciplinary research, serving as leaders, role models, and catalysts. They accumulate substantial practical wisdom through teaching practice and reflection, focusing on guiding and inspiring students in classroom teaching, supporting student inquiry, discussion, and reflection, which benefits the cultivation of students' higher-order thinking[13]. Novice teachers, still in the exploratory and accumulative phase of subject teaching, student development, and disciplinary research, tend to emphasize knowledge transmission and procedural implementation in classroom teaching, with the cultivation of students' higher-order thinking being in an initial exploratory stage[14, 15].

Therefore, to conduct a comparative analysis of classroom teacher-student dialogue between expert and novice teachers, this study employs literature analysis and grounded theory methods to construct an analytical framework for teacher-student dialogue in smart classrooms. Using lag sequential analysis, it analyzes the forms and patterns of teacher-student dialogue among expert and novice teachers, aiming to address the following research questions:

(1) What is the analytical framework for teacher-student dialogue in smart classrooms?

(2) What are the forms of teacher-student dialogue in smart classrooms for novice and expert teachers, and what are the differences?

(3) What are the patterns of teacher-student dialogue in smart classrooms for novice and expert teachers, and what are the differences?

Addressing these questions will contribute to enhancing classroom teaching quality, promoting the development of students' higher-order thinking, and providing a reference for the professional growth of novice teachers.

Literature Review

Research on Cultivating Higher-Order Thinking

Higher-order thinking refers to mental activities or cognitive abilities occurring at relatively high cognitive levels. In Bloom's taxonomy of educational objectives in the cognitive domain, it points towards analysis, evaluation, and creation[16]. It is a crucial quality for scaling technological heights and pioneering new research fields. In recent years, higher-order thinking has become one of the core qualities enabling innovative talents in the 21st century to lead technological innovation and social development. The development of higher-order thinking holds strategic significance for cultivating innovative talents and enhancing national innovation capacity, garnering attention across various fields domestically and internationally. Previous research has explored the nature of higher-order thinking, for instance, characterizing it as flexible, self-regulated, and complex thinking capable of generating multiple solutions and evaluation criteria[17]. Higher-order thinking encompasses problem-solving, decision-making, critical thinking, and creative thinking abilities[18]. At the level of educational practice, some researchers have investigated teaching models, developmental systems, and influencing factors[19]; explored instructional design, teaching models, and learning environments that promote the development of higher-order thinking[20]; examined cultivation models for higher-order thinking based on deep learning[21]; and explored digital twin smart teaching models aimed at cultivating higher-order thinking skills[6]. In summary, research on higher-order thinking has progressed from theoretical construction to diverse practices, requiring further deep integration into teaching and learning activities.

Relationship Between Teacher-Student Dialogue and Cultivation of Higher-Order Thinking

Classroom teacher-student dialogue refers to the process of verbal communication between teachers and students centered around educational objectives[10]. Such dialogue typically requires one subject to initiate a question or conversation, with at least one subject providing a verbal response[22], which can be described using the Initiation-Response-Feedback (IRF) structure[23]. Based on patterns of teacher-student dialogue, researchers have constructed coding frameworks. For example, some have developed an AI-based teacher-student dialogue analytical framework encompassing three dimensions: questioning/initiation, answering, and evaluation/feedback[10]. Others have proposed a high-quality classroom dialogue framework comprising four dimensions: analysis and interpretation, summarization, response construction, and transfer and application, using this framework to assess the validity of classroom dialogue[24]. Another coding framework for dialogue has been constructed containing eight dimensions: basic knowledge, personal expression, analysis and argumentation, comparison and induction, transfer and innovation, response construction, agreement and questioning, and instruction and guidance[25]. High-quality classroom dialogue contributes to students' in-depth understanding of instructional content, promotes the development of analytical and inductive thinking, and is significantly important for the development of students' practical and innovative abilities[26].

Relationship Between Smart Classrooms and Teacher-Student Dialogue

Smart classrooms refer to intelligent and efficient learning environments guided by learning theories such as constructivism and connectivism, aimed at promoting the development of students' core competencies through the use of technologies like artificial intelligence, big data, and learning analytics[27]. As a classroom deeply integrating intelligent technology with smart teaching, a core characteristic of smart classrooms is their strong dialogic nature[28, 29]. Teacher-student dialogue in smart classrooms is diverse and complex[30], encompassing not only interpersonal dialogue between teachers and students, and among students, but also comprehensive dialogue among teachers, students, and technology, with intelligent technology serving as the medium[31]. Current research on teacher-student dialogue in smart classrooms primarily focuses on analytical frameworks and methods. For instance, based on the Flanders Interaction Analysis System, some researchers have constructed an evaluation framework for teacher-student dialogue in smart classrooms, comprising four indicators: teacher verbal behavior, student verbal behavior, teacher technology use behavior, and student technology use behavior[32]. Others have used the Flanders Interaction Analysis method to analyze teacher-student behavior ratios, teacher questioning, student speaking, teacher verbal functions, technology use behaviors, and types of teacher-student interaction in smart classrooms[33]. Lag sequential analysis has been employed to analyze teaching behaviors in smart classrooms[34]and to analyze teacher-student dialogue patterns, identifying four types of teacher-student dialogue patterns in smart classrooms: problem identification, solution conception, solution verification, and artifact creation[7].

In a word, higher-order thinking, as a core competency for innovative talents in the 21st century, has received widespread attention from researchers. Cultivating higher-order thinking relies on refined instructional design and rich teaching practices. Classroom teacher-student dialogue, as a crucial pathway for promoting higher-order thinking development, can effectively enhance students' higher-order thinking skills such as analysis, evaluation, and creation through high-quality dialogue and feedback mechanisms. Intelligent technologies in smart classrooms provide a more intelligent and efficient platform for teacher-student dialogue, enriching dialogue forms and promoting deeper integration of technology and teaching. Currently, research on teacher-student dialogue has formed a relatively rich theoretical system. Analytical frameworks for teacher-student dialogue in smart classrooms are primarily based on modifications of the Flanders Interaction Analysis System, with lag sequential analysis being the main analytical method. The former pays less attention to the development of students' higher-order thinking, while the latter can effectively uncover patterns and characteristics of teacher-student dialogue in smart classrooms. This study draws upon relevant research findings on teacher-student dialogue and smart classroom teacher-student dialogue to construct an analytical framework. Using lag sequential analysis to explore dialogue patterns, this study holds significant implications for promoting the development of students’ higher-order thinking.

Methodology

Method

This study employs literature analysis, grounded theory, and lag sequential analysis, combining quantitative and qualitative approaches. The research process consists of four steps: (1) Extraction of primary dimensions: Using literature analysis, primary dimensions of teacher-student dialogue in smart classrooms were extracted based on analyses of teacher-student dialogue patterns, teacher-student dialogue evaluation index systems, and smart classroom inquiry-based learning models. (2) Extraction of secondary dimensions: Using grounded theory methods, smart classroom teaching videos were coded and analyzed to extract secondary dimensions for the teacher-student dialogue framework. (3) Using lag sequential analysis, lesson examples from the China Smart Education Resource Public Service Platform were selected, coded, and analyzed to inductively extract the forms and patterns of teacher-student dialogue in smart classrooms. The research method process is shown in Fig. 1.

The study was approved by the Academic Ethics Committee of Qujing Normal University. All methods were carried out in accordance with the relevant guidelines and regulations. The research involving human participants complied with the Declaration of Helsinki. The participants provided their written informed consent to participate in this study.

Note

LATSD, Literature Analysis on Teacher-Student Dialogue; EoPD, Extraction of Primary Dimensions; EoSD, Extraction of Secondary Dimensions; CoAF, Construction of an Analytical Framework; CASAP, The analysis of conversational styles and patterns.

Sample

This study selected lesson examples from the China Smart Education Resource Public Service Platform for Primary and Secondary Schools as the research object. This platform aggregates teaching lessons from primary and secondary school teachers across various regions in China. Teachers voluntarily conduct classes in smart classrooms, record them, and upload the videos to the platform. The selection of lesson examples from this platform was based on two considerations: firstly, the lessons on this platform cover major provinces and cities in China; secondly, the open-source data provided by the platform facilitates comparison and validation. Additionally, the platform is officially supported and operated by the Chinese Ministry of Education, ensuring high authority and advancement. This study selected multiple subjects, including Chinese, Mathematics, and Science. Ten unrated lessons and ten Ministry-level Excellent lessons were randomly selected from each subject category as sample data, representing the smart classroom teaching situations of novice and expert teachers, respectively.

Instrument

This study drew upon classroom teacher-student dialogue patterns[24, 35, 11], classroom dialogue evaluation index systems[36–38], and smart inquiry-based learning models[38–39] to extract five primary dimensions of teacher-student dialogue in smart classrooms: problem identification, solution conception, decision evaluation, evaluation and revision, and summarization and reflection. Using

grounded theory methods with a three-level coding approach, 14 secondary dimensions for teacher-student dialogue in smart classrooms were identified. Based on this, a coding system for teacher-student dialogue in smart classrooms was constructed, comprising five primary dimensions and 14 secondary dimensions. The coding system is categorized into five major types: Problem Identification (analyzing problems, posing problems, justifying problems); Solution Conception (designing solutions, reporting solutions, justifying explanations); Decision Evaluation (selecting solutions, verifying solutions, evaluation and analysis); Evaluation and Revision (process evaluation, outcome evaluation, revision and improvement); Summarization and Reflection (summarization, reflective exchange). Specific coding behaviors are shown in Table 1.

Table 1
Coding Table for Teacher-Student Dialogue Behaviors in Smart Classrooms

Primary Dimension	Secondary Dimension	Code	Description
Problem Identification	Analyzing Problems	A1	The teacher designs guiding questions; students use smart devices to answer; the teacher provides feedback based on responses.
	Posing Problems	A2	After in-depth analysis guided by the teacher, students pose challenging questions; smart devices push resources; the teacher provides comments and feedback.
	Justifying Problems	A3	The teacher designs problems; students justify on smart platforms; the teacher guides and provides feedback to ensure scientific validity.
Solution Conception	Designing Solutions	B1	The teacher creates scenarios to stimulate student interest; students gather materials on smart platforms and design multiple solutions; the teacher provides guidance.
	Reporting Solutions	B2	Students present solutions on smart terminals, clearly articulating their design rationale; smart platforms provide feedback; the teacher offers comments.
	Justifying Explanations	B3	Students justify solutions on smart terminals; smart platforms provide feedback; the teacher guides and encourages interaction.
Decision Evaluation	Selecting Solutions	C1	The teacher designs evaluative questions; students engage in discussions using smart platforms; the teacher provides feedback for adjustments to ensure correctness.
	Verifying Solutions	C2	Students verify solutions on smart platforms; the teacher guides hands-on practice; smart platforms provide feedback to help students analyze and improve problems.
	Evaluation and Analysis	C3	Students conduct comprehensive evaluations of verified solutions; the teacher guides critical thinking; smart platforms provide data support to analyze strengths and weaknesses.
Evaluation and Revision	Process Evaluation	D1	Students conduct real-time evaluations using smart platforms; the teacher provides feedback and guidance based on data.
	Outcome Evaluation	D2	Students conduct summative evaluations using smart platforms, performing intuitive analysis based on data; the teacher guides in-depth discussion to comprehensively assess solution effectiveness.

Primary Dimension	Secondary Dimension	Code	Description
	Revision and Improvement	D3	Students revise evaluation plans; the teacher guides dialogue to optimize and improve research plans.
Summarization and Reflection	Summarization	E1	Students review the problem-solving process; smart platforms provide feedback; the teacher guides summarization.
	Reflective Exchange	E2	Students engage in deep reflection; smart platforms provide examples; the teacher guides discussion to identify shortcomings and learn from strengths and experiences.

Data Collection and Organization

Two professional researchers were invited to independently code the smart classroom teaching videos. Sampling was conducted every 8 seconds, recording the main categories of teacher-student dialogue behaviors occurring within each 8-second interval in chronological order. A consistency check of the coding sequences from the two coders was performed. The results indicated that Cohen's Kappa coefficient values for all video codings were greater than 0.75, indicating suitability for sequential analysis.

The coded data were imported into the General Sequential Querier (GSEQ) software for quantitative analysis. After processing, transition frequency tables for teacher-student dialogue behaviors were generated. The transition frequencies for expert and novice teachers are shown in Appendices S1 and S2, respectively. With the transition relationships of dialogue behaviors as the core, the first column represents the preceding dialogue behavior, and the first row represents the succeeding dialogue behavior. The values reflect the actual frequency of transitions from the preceding dialogue behavior to the succeeding one. After analysis, 2,981 and 2,064 sequences of dialogue behavior relationships were identified, respectively.

To further reveal the statistical significance of these dialogue behavior sequence relationships, the data in Appendices S1 and S2 were processed to obtain adjusted residuals (Z-scores), as shown in Appendices S3 and S4. The Z-score, as a key indicator for statistical testing, objectively assesses the significance level of dialogue behavior transition relationships. When the Z-score value exceeds 1.96, these dialogue behavior transition relationships are deemed statistically significant[46]. Based on this, 36 and 28 significant dialogue behavior sequences were identified, respectively.

Results

Comparative Analysis of Classroom Dialogue Frequency Between Expert and Novice Teachers

The frequencies of classroom dialogue for expert and novice teachers are shown in Fig. 2. It can be observed that expert teachers engage in relatively high and balanced frequencies of dialogue across the five stages of the smart inquiry process. This indicates that expert teachers emphasize having students experience smart inquiry activities such as problem identification, solution conception, decision evaluation, evaluation and revision, and summarization and reflection, thereby facilitating the development of students' higher-order thinking through complete inquiry activities. Novice teachers primarily focus on dialogue related to problem identification, while dialogue related to solution conception, decision evaluation, summarization and reflection—particularly evaluation and revision—is severely insufficient. In some cases, frequencies for reporting solutions (B2), justifying explanations (B3), evaluation and analysis (C3), process evaluation (D1), outcome evaluation (D2), revision and improvement (D3), and reflective exchange (E2) are zero. This suggests that novice teachers emphasize only the problem identification stage of inquiry, merely having students identify problems without focusing on analyzing and solving them, making it difficult to develop students' higher-order thinking.

Comparative Analysis of Dialogue Sequences Between Expert and Novice Teachers in Smart Classrooms

Using lag sequential analysis, classroom dialogue pattern diagrams for expert and novice teachers were created, as shown in Figs. 3 and 4. In these diagrams, nodes represent dialogue types, edges (depicted as directed paths) describe relationships between different dialogues, and line thickness indicates the degree of correlation between the two types of dialogue—i.e., the probability of one dialogue type occurring after another. Arrow directions represent the sequential order of different dialogues.

Analysis of Expert Teachers’ Smart Classroom Dialogue

As shown in Fig. 3, the sequences with higher dialogue frequencies for expert teachers include: A1 → A3 → C1 → C2 → C3 → A1 (or C1). Guided by the teacher, students conduct in-depth analysis of the problem (A1). To ensure the accuracy of the problem, students use subject-specific software tools on smart platforms to justify the problem (A3). After identifying and confirming the research problem, students need to select a research plan. Through selecting solutions (C1), students engage in discussions and debates on smart platforms, preliminarily screening feasible solutions. During the solution verification stage (C2), the teacher organizes students to conduct hands-on verification on smart platforms, which provide real-time data feedback to help students adjust solutions. After verification, to ensure accuracy, the teacher organizes students to conduct a comprehensive evaluation (C3), guiding critical thinking to analyze solution strengths and weaknesses. Through this cycle of practice and evaluation, students may identify new research problems, requiring a return to the analyzing problems (A1) or re-selecting solutions (C1) stage, forming an iterative, spiraling upward problem-solving loop that deepens understanding of the problem.

 A1 → A3 → D1 (or → D2) → D3 → A2. Under the teacher's organization and guidance, students understand the nature of the problem through analyzing problems (A1), then conduct logical reasoning and data analysis on smart platforms to justify the accuracy and rationality of the problem (A3). During this process, students conduct real-time evaluations (D1) or summative evaluations (D2) on smart platforms, identifying issues based on evaluative feedback. Based on evaluation results, the teacher guides students to revise and improve the research plan (D3). This revision process encourages students to think more deeply, posing more challenging and innovative problems (A2), forming a closed loop from analyzing problems to posing problems, then to evaluating and revising problems, stimulating new thinking, thereby promoting the development of students' problem-solving skills and innovative thinking.

 A1 → A3 → B1 → B2 → B3 → A1. Guided by the teacher, students analyze the problem (A1), clarifying its core and key aspects. They conduct in-depth practical justification on smart platforms (A3), ensuring a deep understanding of the problem. Based on the analysis results, students use smart platforms to gather materials and design multiple innovative solutions (B1). After designing solutions, students present them via smart terminals, clearly articulating the design rationale and steps (B2). This stage not only exercises students' expression skills but also ensures solution feasibility through smart platform feedback and teacher comments. Next, students justify the rationality of the solutions (B3), with smart platforms providing necessary technical support and the teacher's in-depth guidance and interaction ensuring accuracy and depth. Subsequently, students may identify new research problems, possibly returning to the analyzing problems stage (A1), forming a cyclical, deepening problem-solving process. This process promotes the development of students' problem-solving skills while cultivating their innovative and critical thinking abilities.

 A1 → A3 → B1 → B3 → B1 → B3 → A1 → B2 → B3 → A1. Students form a deeply cyclical and continuously optimizing pattern in the learning process. First, the teacher inspires student thinking by designing guiding questions (A1), then guides students through logical reasoning and data analysis to justify the problem (A3). Based on this, students design solutions (B1) and initially justify the scientific validity and rationality of the solutions (B3). This process requires continuous revision and improvement; students re-enter the stages of designing solutions (B1) and justifying explanations (B3) for iteration and optimization, reflecting students' ongoing reflection and improvement during problem-solving. When students feel the solution is mature, they return to the analyzing problems stage (A1) to re-examine the problem, ensuring no information is missed. Students present the solution on smart terminals (B2), articulating the design rationale and receiving feedback from smart platforms and the teacher, which helps them further refine the solution. Through justifying explanations (B3), students not only deepen their understanding of the problem but also enhance their problem-solving skills. This cyclical process cultivates students' innovative and critical thinking skills while ensuring they can respond flexibly to complex problems, continuously seeking optimal solutions. This deep learning model helps students form systematic knowledge structures and problem-solving strategies.

 A1 → A3 → B1 → B2 → B3 → E1 → E2 → E1 → E2 → B1 → A1. Students demonstrate a complete cycle from problem identification, analysis, solution conception, and practical verification to summarization, reflection, revision, and improvement. The teacher stimulates learning motivation and inspires thinking through guiding questions (A1), then guides students through logical reasoning and data analysis to rigorously justify the problem (A3), laying a solid foundation for subsequent solution design. Based on problem analysis results, students use smart platforms to gather materials and design solutions (B1), presenting them on smart terminals and clearly articulating steps and rationale (B2). Through smart platform feedback and teacher comments, students further justify the solutions (B3), ensuring feasibility and accuracy. After completing the initial solution design, they enter the summarization and reflection stage, reviewing the problem-solving process (E1), integrating materials via smart platforms to deepen understanding. Based on this, students draw on examples from smart platforms and peers' work for deep reflection (E2), identifying shortcomings in the solution. Through repeated summarization and reflection (E1 → E2 → E1 → E2), they continuously revise and improve the solution design. When the solution is relatively mature, they return to the solution design stage (B1) for fine-tuning based on previous reflections and experience. Subsequently, they re-enter the problem identification stage (A1), examining the problem from a new perspective to ensure the solution addresses it. This cycle reflects students' initiative and creativity in learning and promotes the development of their problem-solving skills and innovative thinking.

Analysis of Novice Teachers' Smart Classroom Dialogue

As shown in Fig. 4, the sequences with higher dialogue frequencies for novice teachers include: E1 → E2 → E1. Students review the problem-solving process through summarization (E1). Subsequently, they enter the reflection stage (E2), identifying shortcomings and learning from strengths. Students then summarize again (E1), extracting more valuable information.

 D1 → D2 → D3 or D1 → D3. Students evaluate on smart platforms (D1), receiving process-oriented feedback to facilitate continuous improvement of the solution. Next, they conduct summative evaluation (D2), using data for intuitive analysis to comprehensively assess solution effectiveness. Finally, they revise the solution based on evaluation results (D3), with smart platforms pushing relevant learning resources to assist students in problem-solving.

 C1 → C2 → C3 → C1. Based on smart platform analysis results, under teacher organization, students engage in group discussions and exchanges, selecting a research plan (C1). To ensure feasibility, they verify the plan using smart platforms under teacher guidance (C2). After verification, they conduct a comprehensive evaluation (C3), gaining insight into the solution's strengths and weaknesses. Subsequently, they re-enter the solution selection stage (C1), but this time, based on more information and experience, they can make more optimal choices. This sequence reflects a cyclical, iterative learning process, promoting continuous improvement and optimization of the solution.

 A1 → A2 → A1 → A2 (or → B1) → B2 → B3. With teacher guidance and assistance, students conduct in-depth analysis of the problem (A1), posing a clear research question (A2). Posing a question is more

important and challenging than solving it; therefore, this process needs repetition (A1 → A2 → A1 → A2). To solve the problem, students need to conceive solutions. Based on the problem analysis results, they propose initial designs (B1), present and clearly articulate the design rationale via smart terminals (B2). With smart platform support, students justify the solution's rationality, with the teacher interacting to ensure accuracy (B3). This dialogue process promotes the development of students' problem-solving skills, from problem analysis to solution design to justification, forming a complete learning process.

 A1 → A2 → A1 → A2 → B1 (or → B2) → B3 → B1. The teacher designs research questions, pushes them to students via smart platforms; students conduct in-depth analysis (A1), and with teacher guidance and assistance, pose a clear research question (A2). The recurrence of this process (A1 → A2 → A1 → A2) reflects the spiraling upward of students' in-depth understanding and analytical skills. After posing a clear research question, to solve it, students need to conceive solutions. They may directly begin designing solutions based on prior problem analysis (B1), or first present initial plans on smart terminals for feedback (B2), then engage in solution justification (B3). After justification, students may identify shortcomings and need to return to the solution design stage (B1) for improvement. This process reflects students' continuous trial, error, revision, and improvement during learning.

 A1 → A2 → A1 → A2 (or → A3) → B1. The teacher designs research questions, pushes them to students via smart platforms; students conduct in-depth analysis (A1), and with teacher guidance and assistance, pose a clear research question (A2). They deepen understanding by analyzing the problem again (A1) or ensure rigor and scientific validity by justifying the problem (A3). Based on this, they enter the solution conception stage, designing solutions (B1). This process reflects the journey from problem identification to analysis, then to proposing innovative solutions based on analysis. Through repeated analysis and justification, students can comprehensively understand the problem, laying the groundwork for designing innovative solutions.

Discussion

Dialogue Frequency Affects the Development of Students' Higher-Order Thinking

At the level of statistical analysis of dialogue frequency, this study found that expert teachers engage in diverse forms of teacher-student dialogue, including discovery, conception, decision-making, evaluation, and summarization dialogues. In contrast, novice teachers exhibit a relatively singular dialogue form, primarily discovery-oriented. This finding aligns closely with research by Yu and Huang (2025) on the characteristics of classroom discourse of expert elementary mathematics teachers in China, which noted that expert teachers initiate discussions by posing a limited number of higher-order questions, construct discourse chains based on student responses, and build thinking scaffolds through timely follow-up questions to help students continuously advance their thinking. This study further reveals the sequential characteristics of expert teachers' dialogue patterns: in the cyclical sequence A1 (analyzing problems) → A3 (justifying problems) → C1 (selecting solutions) → C2 (verifying solutions) → C3

(evaluation and analysis) → A1 (re-analysis), students continuously experience a spiraling process of “analysis—justification—selection—verification—evaluation—re-analysis.” This sequential characteristic aligns with the interactive mechanisms of “response construction” and “transfer and application” within the high-quality classroom dialogue framework proposed by Song et al. (2021).

Furthermore, during discovery-oriented dialogue, expert teachers design guiding questions, use smart platforms and devices to collect student responses, and provide feedback. This dialogue form not only helps students identify problems but also promotes in-depth analysis. During conception-oriented dialogue, expert teachers create scenarios to stimulate student thinking, guiding them to use smart platforms to gather information and design solutions. This form helps students identify problems and promotes in-depth analysis[24, 41]. During decision-oriented dialogue, expert teachers design evaluative questions, use smart platforms for analysis, and guide student group discussions to narrow choices. This form helps students learn to weigh pros and cons and make informed decisions[42, 43]. During evaluation-oriented dialogue, expert teachers guide students to use smart platforms for real-time and summative evaluations, using data feedback to guide improvement. This form promotes students' in-depth understanding and comprehensive evaluation of solutions[44–46].During summarization-oriented dialogue, expert teachers guide students to review the problem-solving process, integrate materials using smart platforms, and summarize key points. The “summarization” dimension in the classroom dialogue framework proposed by Song et al. (2020) emphasizes teacher guidance in reviewing problem-solving processes and extracting core points. Song et al. (2021) further revealed the mechanism by which teachers help students complete knowledge integration and experience transfer through “response construction”. Li's (2023) study on the post-lesson reflection characteristics of expert teachers indicated that they focus on guiding students to form a complete knowledge framework, providing a cognitive basis for summarization-oriented dialogue. Overall, expert teachers flexibly utilize these dialogue forms to create diversified teacher-student dialogue patterns, thereby more effectively promoting the development of students' higher-order thinking. In contrast, novice teachers employ a more singular dialogue form, primarily discovery-oriented. They focus more on having students discover research problems while lacking in-depth dialogue during the conception, decision, evaluation, and summarization stages. This singular dialogue form may limit the development of students' thinking and problem-solving abilities. Students may lack sufficient opportunities to innovate, evaluate, and improve their solutions, thereby affecting their learning outcomes.

Dialogue Sequence Affects the Development of Students’ Higher-Order Thinking

At the level of dialogue sequences, the dialogue patterns of expert teachers generally follow the complete smart inquiry-based learning process of discovery-conception-decision-evaluation-summarization, exhibiting diversified characteristics. These include four typical patterns: discovery-decision, discovery-evaluation, discovery-conception, and discovery-conception-summarization. In contrast, novice teachers exhibit relatively singular dialogue patterns, including decision-oriented, evaluation-oriented, summarization-oriented, and discovery-conception patterns. Expert teachers’

dialogue patterns generally adhere to the complete problem-solving process of“discovery-conception-decision-evaluation-summarization”. This pattern not only reflects the logic and systematic nature of the teaching process but also demonstrates the comprehensiveness and depth of expert teachers in guiding students to solve problems [37, 47]. Expert teachers can flexibly employ multiple dialogue patterns, switching between them adeptly, allowing them to adjust teaching strategies based on different problems and student needs, ensuring teaching effectiveness and relevance. During dialogue, expert teachers focus on guiding students to think deeply, analyze, and solve problems. They attend not only to students’ problem identification skills but also to cultivating their conception, decision-making, evaluation, and summarization abilities. This comprehensive dialogue pattern contributes to enhancing students’ overall competence and problem-solving skills[48, 49]. Expert teachers encourage students to actively express opinions, raise questions, and engage in critical thinking during dialogue. Through questioning, guidance, and feedback, they stimulate student thinking and promote deep learning[50, 51, 26]. Research indicates that expert teachers flexibly use various discourse strategies—such as clarifying questions, restatements, challenging questions, and extending questions—to promote students’ cognitive development within their zone of proximal development[52]. The strategy of follow-up questioning is particularly crucial: focusing not only on the initial question but also on subsequent questions—such as “Why do you think so?” or “How does this idea connect to...?”—moves student thinking from “recall” to “analysis, evaluation, creation”[53]. In contrast, novice teachers’ dialogue patterns are relatively singular, primarily including “decision-oriented”,“evaluation-oriented”, “summarization-oriented”, and “discovery-conception”patterns. Although these patterns involve different stages of problem-solving, they lack systemicity and completeness. Novice teachers often focus more on a specific stage of teaching during dialogue, neglecting the importance of other stages. For example, they may focus more on students' decision-making or evaluation skills while overlooking the cultivation of problem identification and conception abilities.

Conclusions

To better construct high-quality, effective smart classrooms and promote the development of learners' higher-order thinking skills, this study employed literature analysis, grounded theory methods, and lag sequential analysis to compare and analyze the forms and patterns of teacher-student dialogue in smart classrooms between novice and expert teachers, reaching the following conclusions:

(1) The analytical framework for teacher-student dialogue in smart classrooms comprises five primary dimensions: problem identification, solution conception, decision evaluation, evaluation and revision, and summarization and reflection. Each dimension can be analyzed from three aspects: problem design, problem answering, and problem feedback. Each primary dimension further contains 2–3 secondary indicators.

(2) Novice teachers exhibit a relatively singular form of classroom teacher-student dialogue, primarily discovery-oriented. Expert teachers demonstrate diverse forms of classroom teacher-student dialogue,

including discovery-oriented, conception-oriented, decision-oriented, evaluation-oriented, and summarization-oriented forms.

(3) Novice teachers display relatively singular dialogue patterns, including decision-oriented, evaluation-oriented, summarization-oriented, and discovery-conception patterns. Expert teachers' dialogue patterns generally follow the discovery-conception-decision-evaluation-summarization pattern, exhibiting diversified characteristics. These include four typical patterns: discovery-decision, discovery-evaluation, discovery-conception, and discovery-conception-summarization.

Declarations

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Author Contribution

LQ, XM, and DX: conceptualization. LQ and XM: methodology, formal analysis, and writing-original draft preparation. LQ and XM: data collection, writing-review, and editing. DX: supervision and project administration. All authors contributed to the article and approved the submitted version.

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Figures

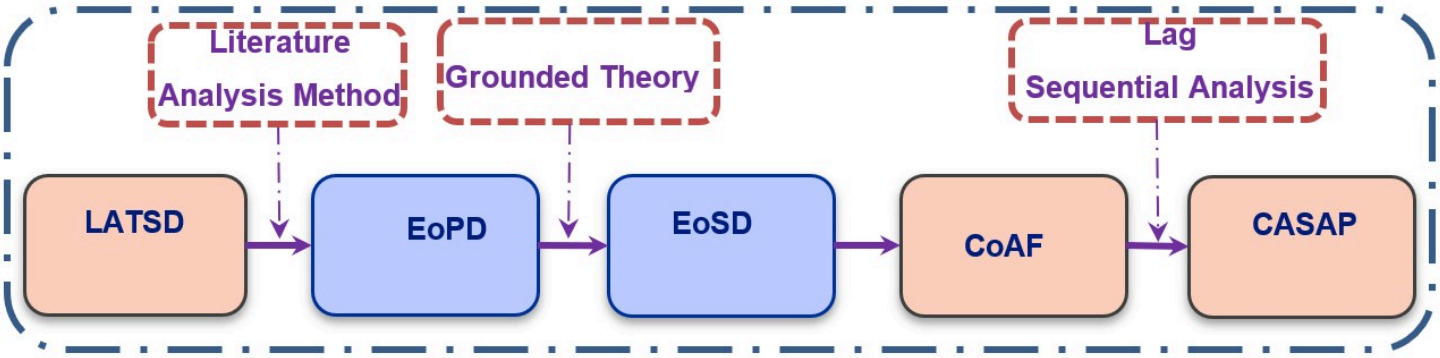

Figure 1

Research Method Flowchart

Note. LATSD, Literature Analysis on Teacher-Student Dialogue; EoPD, Extraction of Primary Dimensions; EoSD, Extraction of Secondary Dimensions; CoAF, Construction of an Analytical Framework; CASAP, The analysis of conversational styles and patterns.

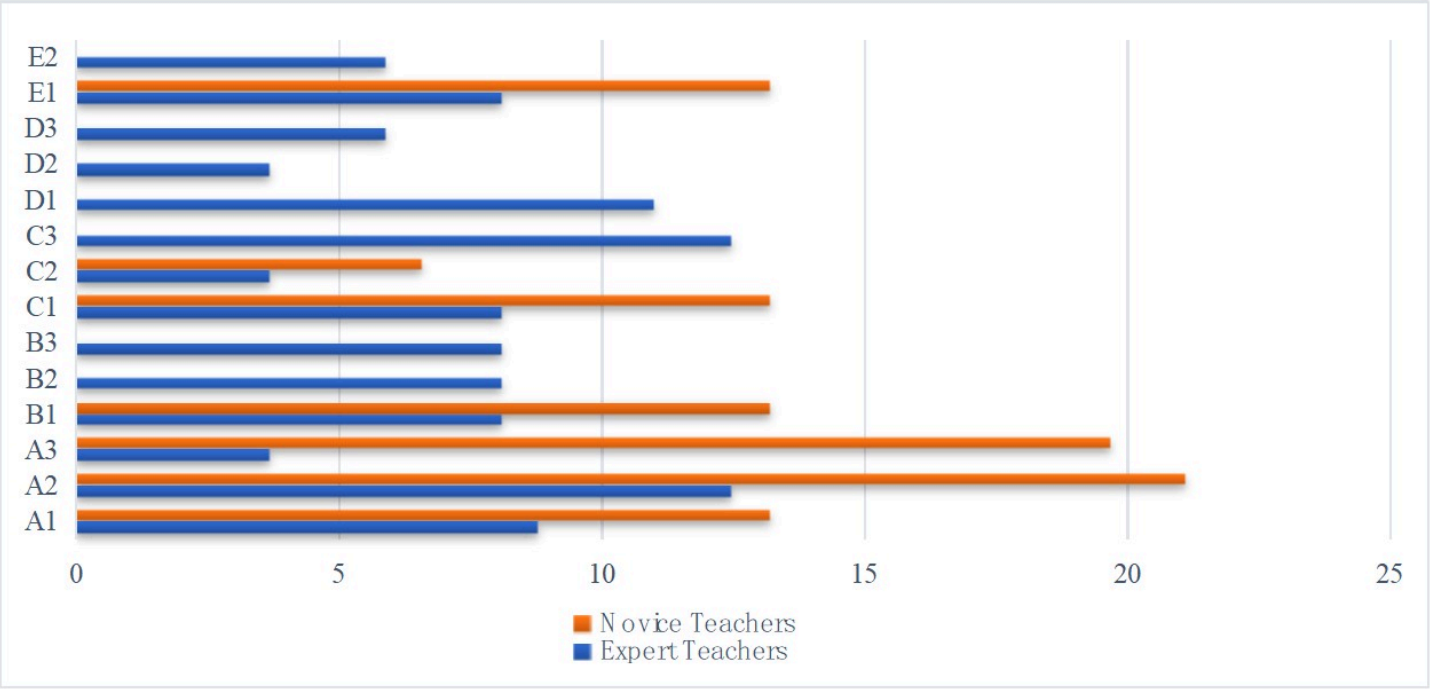

Figure 2

Comparison of Dialogue Frequency Between Expert and Novice Teachers in Smart Classrooms

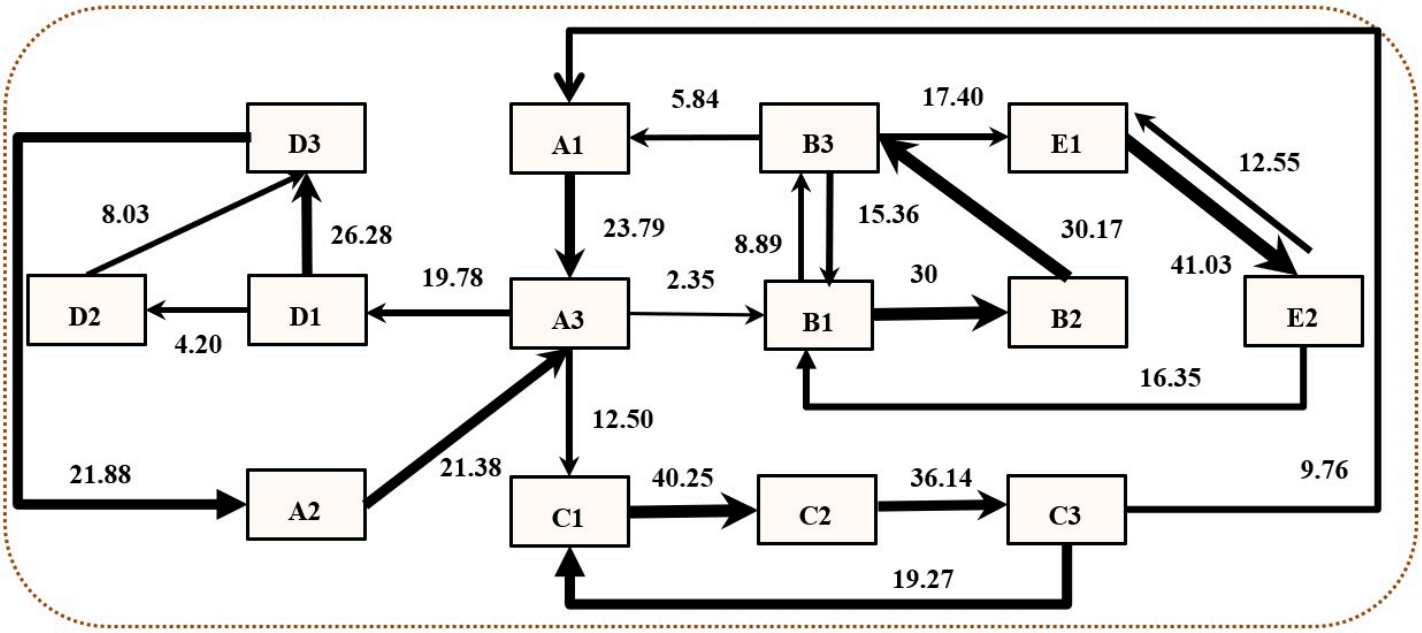

Figure 3

Classroom Dialogue Pattern of Expert Teachers

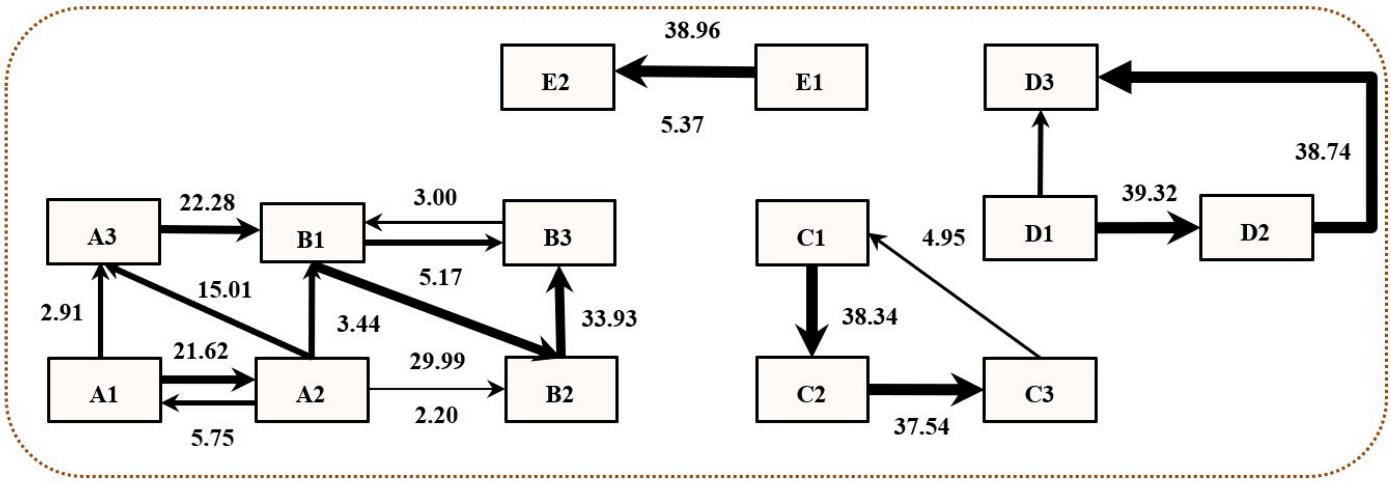

Figure 4

Classroom Dialogue Pattern of Novice Teachers

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