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Effects of Blackboard Teaching and PPT Teaching in High School Mathematics Classroom Based on Cognitive Load Theory

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Abstract

The knowledge system of high school mathematics is extensive, logically rigorous, highly abstract, and challenging. Reasoning-based teaching is the primary method, with blackboard teaching and PPT teaching being common instructional tools. This study, based on cognitive load theory, explores the effectiveness of these two teaching methods in high school mathematics classrooms. First, it explains the concept of cognitive load, including intrinsic, extraneous, and germane cognitive load. Then, it analyzes how blackboard teaching and PPT teaching affect students' cognitive load. Blackboard teaching, characterized by its gradual presentation and simplicity, has unique advantages in controlling cognitive load, helping students gradually build their mathematical knowledge system and reducing extraneous cognitive load. PPT teaching, known for its integration of multimedia elements and dynamic demonstrations, can enhance the learning experience, but improper use may increase irrelevant cognitive load for students. Through classroom observation, student surveys, and performance analysis, the study finds that blackboard teaching is more helpful for students in understanding basic concepts and logical reasoning, thereby reducing cognitive load. PPT teaching plays a positive role in demonstrating complex mathematical figures and introducing real-life examples, but it must be designed carefully to avoid cognitive overload. The results suggest that a flexible combination of blackboard and PPT teaching, tailored to different teaching content, can optimize high school mathematics instruction, distribute students' cognitive resources more effectively, and improve their learning efficiency in mathematics.

Subject Areas

Mathematics Education

Keywords

Cognitive Load Theory, High School Mathematics, Blackboard Teaching, PPT Teaching, Teaching Effectiveness

1. Introduction

High school mathematics is a subject that requires students to have strong logical thinking and abstract understanding abilities. The choice of teaching methods significantly impacts students' learning outcomes. Blackboard teaching, as a traditional instructional method, is characterized by its direct and step-by-step presentation of knowledge, whereas PPT teaching, as a product of modern information technology applied in education, offers advantages like high information integration and convenient dynamic demonstrations. Cognitive load theory focuses on the allocation of cognitive resources during the learning process. Researching the effects of these two teaching methods in high school mathematics based on cognitive load theory helps optimize teaching strategies and improve teaching quality. As Sweller (1988) pointed out in his early research on cognitive load theory, an appropriate teaching method should avoid imposing excessive cognitive load on learners to improve learning efficiency [1].

2. Overview of Cognitive Load Theory

Cognitive Load Theory examines the mental effort required during learning. It includes intrinsic cognitive load, determined by the complexity of material and prior knowledge, such as understanding composite functions in mathematics. Extraneous cognitive load arises from poor instructional design, like cluttered PPTs. Germane cognitive load focuses on schema construction, enhancing knowledge retention and transfer.

2.1. The Concept of Cognitive Load

Cognitive load refers to the total amount of cognitive resources required by working memory when performing a specific cognitive task, such as learning. It reflects the mental effort learners face during the learning process, encompassing the challenges of processing new information, integrating it with existing knowledge, and applying it to problem-solving scenarios. Understanding cognitive load is crucial for designing effective educational strategies that optimize learning and retention.

2.2. Types of Cognitive Load

Cognitive load is categorized into intrinsic, extraneous, and germane types. Intrinsic cognitive load arises from the complexity of the material and prior knowledge, as seen in understanding composite functions. Extraneous cognitive load stems from poor instructional design, hindering learning. Germane cognitive load focuses on schema construction, enhancing knowledge retention and transfer.

2.2.1. Intrinsic Cognitive Load

Intrinsic cognitive load is determined by the complexity of the learning material itself and the learner's prior knowledge level. In high school mathematics, for example, learning complex function concepts and properties naturally imposes a certain intrinsic cognitive load due to the abstract nature and interconnectedness of the concepts. For instance, learning the differentiation rule of composite functions requires students to understand the nested structure of functions and analyze multiple layers of relationships, which demands a solid foundation in functions and logical thinking abilities. According to Van Merriënboer and Sweller (2005), intrinsic cognitive load is closely related to the inherent characteristics of learning material, and it is difficult to eliminate completely through changes in teaching methods [2].

2.2.2. Extraneous Cognitive Load

Extraneous cognitive load is the additional cognitive burden caused by poor instructional design. For instance, excessive animation effects or complex layouts in PPTs or chaotic and disordered blackboard content can increase students' extraneous cognitive load. Clark (2023) found that extraneous cognitive load interferes with learners' processing of key information and reduces learning effectiveness [3].

2.2.3. Germane Cognitive Load

Germane cognitive load is intricately related to the construction and automation of schemas by learners, which are mental frameworks that help organize and interpret information. This type of cognitive load is beneficial as it directly contributes to meaningful learning and understanding. Effective teaching strategies should aim to guide students in allocating more cognitive resources towards germane cognitive load by encouraging deep processing of information and fostering connections between new and existing knowledge. This approach facilitates long-term knowledge storage and transfer, enabling learners to apply their understanding to new and varied contexts, ultimately enhancing their problem-solving skills and adaptability in different learning situations.

2.3. Detailed Explanation of the Cognitive Load Differences in Algebra and Geometry Teaching

The cognitive load in algebra and geometry teaching differs primarily in their intrinsic demands. Algebra requires abstract symbol manipulation and multi-step problem-solving, leading to a high intrinsic cognitive load. Geometry, on the other hand, often involves spatial reasoning and visual interpretation, which can vary in complexity. Effective teaching addresses these differences to optimize learning.

2.3.1. Cognitive Load in Algebra Teaching

Algebra teaching involves a high intrinsic cognitive load due to abstract symbol manipulation and complex problem-solving steps. Extraneous load can increase through poorly designed materials, while germane load is enhanced as students form connections between algebraic concepts, integrating new and existing knowledge.

1) Intrinsic Cognitive Load

Abstract Symbol Manipulation: Algebra involves a significant amount of symbols and formulas, which require students to have a good understanding of these abstract concepts. For instance, grasping the relationship between variables, coefficients, and constants demands a high intrinsic cognitive load.

Complexity of Steps: Solving algebraic problems often requires multiple steps, such as solving equations or factoring expressions. This requires students to maintain a clear understanding and memory of multiple steps during problem-solving.

2) Extraneous Cognitive Load

Presentation of Teaching Materials: Poorly designed teaching materials (e.g., textbooks or slides) can increase extraneous cognitive load. For example, overly complex examples or unclear step-by-step instructions may confuse students.

Unnecessary Information Interference: Information that is irrelevant to the learning objectives can increase students' extraneous cognitive load.

3) Germane Cognitive Load

Conceptual Connections: Many algebraic concepts are interrelated, such as the relationships between functions, equations, and inequalities. Understanding these connections can increase germane cognitive load as students integrate new information with existing knowledge.

2.3.2. Cognitive Load in Geometry Teaching

Geometry teaching presents unique cognitive load challenges, primarily through spatial reasoning and visual processing demands. Intrinsic load arises from understanding shapes, theorems, and proofs. Effective instruction minimizes extraneous load by using clear diagrams and step-by-step explanations, while fostering germane load by encouraging visualization skills and logical reasoning in problem-solving.

1) Intrinsic Cognitive Load

Spatial Visualization: Geometry requires a lot of spatial imagination and visualization skills, such as understanding the properties of triangles or calculating the volume of 3D shapes. This places high demands on students' spatial cognitive abilities.

Logical Reasoning: Geometric proofs require strong logical reasoning skills, which involve deducing conclusions from given conditions through logical steps.

2) Extraneous Cognitive Load

Complexity of Figures: Complex geometric figures can increase students' extraneous cognitive load, especially when figures contain multiple elements or require multiple annotations.

Use of Multimedia Materials: While dynamic geometry software or animations can aid understanding, improper use can also increase extraneous cognitive load.

3) Germane Cognitive Load

Integration of Theory and Application: Geometry often involves combining theoretical knowledge with practical applications, such as using geometric principles in measurement and construction. This requires students to apply geometric knowledge to real-world problems, increasing germane cognitive load.

2.3.3. Teaching Strategy Suggestions

Algebra Teaching: Teachers can reduce intrinsic cognitive load by breaking down complex problems, using intuitive examples, and providing step-by-step guidance. Additionally, optimizing teaching materials to minimize unnecessary information can reduce extraneous cognitive load.

Geometry Teaching: Utilizing dynamic geometry software and physical models can help students better understand spatial concepts, thereby reducing intrinsic cognitive load. Clear graphical presentations and step-by-step reasoning processes can also help lower extraneous cognitive load.

By adopting strategies tailored to the different types of cognitive load in algebra and geometry teaching, teachers can more effectively assist students in understanding and mastering mathematical concepts.

3. The Impact of Blackboard Teaching on Cognitive Load

The use of blackboard teaching has long been a staple in educational environments, offering a traditional yet effective medium for instruction. Understanding its impact on cognitive load is essential for educators aiming to optimize learning experiences. Cognitive load refers to the amount of mental effort being used in the working memory, and it can significantly influence the effectiveness of teaching methods.

3.1. Characteristics, Advantages, and Disadvantages of Blackboard Teaching

Blackboard teaching, characterized by its physical interaction and visual presentation, remains a widely used method in classrooms. Its characteristics include the ability to present information in a linear fashion, the flexibility to modify content in real-time, and the opportunity for students to engage through note-taking. However, like any teaching method, it has its own set of advantages and disadvantages.

3.1.1. Advantages

Blackboard teaching presents several pedagogical advantages, such as the ability to introduce information gradually and maintain simplicity, thereby aiding in the management of cognitive load. This method allows students to process information incrementally and concentrate on essential concepts. Furthermore, it supports immediate interaction and offers an accessible platform for review, thereby enhancing student engagement and facilitating the consolidation of knowledge. The following points outline the benefits of employing blackboard teaching as an instructional method.

1) Gradual Presentation

In the process of proving theorems in high school mathematics, teachers gradually write down the derivation steps on the blackboard, enabling students to follow the pace. For example, when proving the sum and difference formula for trigonometric functions, $\sin(A+B)=\sin A\cos B+\cos A\sin B$, the teacher first writes down the given conditions, A and B as arbitrary angles, then proceeds to explain using a unit circle, drawing relevant trigonometric lines, and finally performs transformations step-by-step. This gradual presentation aligns with students' cognitive processing and prevents them from overwhelming themselves with too much information at once, thereby reducing extraneous cognitive load. Paas (1992) found that presenting information gradually helps learners better process information in working memory and reduces the risk of cognitive overload [4].

2) Simplicity

A well-designed blackboard lesson usually presents only key points, formulas, and problem-solving steps. For instance, when explaining the general formula of sequences, the teacher simply lists some terms like a_1, a_2, a_3 on the blackboard, and then derives the general formula, demonstrating different methods like observation, summation, or product method. A concise blackboard helps students focus on key information, avoids distractions from irrelevant content, and reduces extraneous cognitive load, allowing students to allocate more cognitive resources to understanding the intrinsic knowledge structure and increasing germane cognitive load.

3) Instant Interaction

During blackboard teaching, teachers can adjust the pace of writing or add supplementary explanations based on students' responses. For instance, when explaining the concept of the angle between skew lines in solid geometry, if the teacher notices confusion among students, they can draw additional examples of skew lines on the blackboard and elaborate on how to transform them into intersecting lines for calculating the angle. This immediate interaction helps teachers better control the teaching pace and meet students' learning needs. Vygotsky's (1978) sociocultural theory emphasizes that interaction during the teaching process has a positive impact on students' learning [5].

4) Convenient for Review and Summary

Blackboard content remains visible on the board for an extended time, which is convenient for students to review during class summaries or revisions, aiding in the consolidation of knowledge. For example, during the revision of conic sections, the key points about ellipses, hyperbolas, and parabolas—including definitions, standard equations, and properties (foci, eccentricity, asymptotes, etc.)—are clearly visible on the blackboard, allowing students to quickly organize the knowledge structure.

3.1.2. Disadvantages

Blackboard teaching is constrained by its limited capacity for information, inability to illustrate dynamic concepts, and inflexibility in making corrections, all of which can impede the effective presentation of complex topics. The following are specific disadvantages associated with practical blackboard teaching.

1) Limited Information Capacity

Due to the limited space on the blackboard, it cannot present as much information as PPT can. For topics with extensive content and complex relationships, it may be difficult to provide a comprehensive overview using only the blackboard. For instance, when reviewing the entire function system in high school mathematics, which includes the domain, range, monotonicity, odd and even properties, periodicity, and inverse functions of various types (e.g., linear, quadratic, exponential, logarithmic, trigonometric functions), it is challenging to present all of the functions and their interrelationships comprehensively using only the blackboard.

2) Lack of Dynamic Effects

When explaining concepts that require dynamic demonstration, such as the dynamic changes of the graph of a function $y = \sin(\omega x + \varphi)$ (how the graph stretches or shifts as A, ω, φ or the motion of geometric shapes like the rotation of a cube around one of its edges, it is difficult for the blackboard to illustrate these changes clearly, which may increase the difficulty of understanding and hence the intrinsic cognitive load.

3) Limited Flexibility

Once the content is written on the blackboard, correcting or adjusting it can be cumbersome compared to the ease of editing in a PPT. For example, if an error is found or modifications are needed during a complex mathematical derivation, erasing and rewriting can take considerable time and may make the board look cluttered.

3.2. The Role of Blackboard Teaching in Different Types of Cognitive Load

Blackboard teaching plays a significant role in managing different types of cognitive load during the learning process. By presenting information in a clear and structured manner, it helps reduce extraneous cognitive load, allowing students to focus on essential content. However, its limitations in demonstrating dynamic concepts can sometimes increase intrinsic cognitive load, particularly when dealing with complex topics that require visualization. To effectively manage germane cognitive load, educators can supplement blackboard teaching with interactive discussions and multimedia resources, enhancing students' understanding and retention of the material.

3.2.1. Intrinsic Cognitive Load

Although blackboard teaching cannot directly reduce the complexity of mathematical knowledge, it helps students gradually break down complex concepts and problems through structured presentation. For instance, in solid geometry, a teacher can draw the three views of a triangular pyramid on the blackboard step-by-step—first drawing the front view to determine the shape of the base triangle and the position of the apex, then the top view, and finally the side view. This gradual drawing helps students understand the relationship between the views, thus alleviating the intrinsic cognitive load to some extent. This approach aligns with De Jong (2010), who found that the orderly presentation of learning materials helps learners process complex knowledge structures [6].

3.2.2. Extraneous Cognitive Load

The simplicity and orderliness of blackboard teaching can effectively avoid extraneous cognitive load caused by too much information or a chaotic presentation. For example, when explaining permutation and combination problems, a teacher can clearly list different cases on the blackboard. In a problem that requires finding the permutation of 5 distinct elements taken 3 at a time A_5^3, the teacher writes out the calculation formula $A_n^m = \frac{n!}{(n-m)!}$, substitutes the values $A_5^3 = \frac{5!}{(5-3)!} = \frac{5\times4\times3\times2\times1}{2\times1} = 5\times4\times3 = 60$, and proceeds step-by-step without overwhelming students with cluttered information, unlike some confusing PPT slides. This approach is consistent with Mayer and Moreno's (2003) conclusion that the orderly presentation of information can reduce extraneous cognitive load [7].

3.2.3. Germane Cognitive Load

Blackboard teaching allows students to better construct a framework of mathematical knowledge in their minds, connecting new knowledge with existing knowledge structures. For instance, during a review of functions in high school mathematics, the teacher can use the blackboard to present key knowledge points, such as domain, range, monotonicity, and symmetry, in a logical framework. Drawing a large bracket on the blackboard, the teacher lists key aspects—how to find the domain (common characteristics of different functions), methods to find the range (e.g., completing the square or substitution), methods for determining monotonicity, steps for verifying whether a function is odd or even, etc. This helps students integrate knowledge and increases germane cognitive load, facilitating long-term memory and transfer of knowledge. This approach is in line with Sweller's (1994) assertion that guiding students in constructing a knowledge framework can enhance germane cognitive load [8].

4. The Impact of PPT Teaching on Cognitive Load

PowerPoint (PPT) teaching significantly influences cognitive load in educational settings by offering a dynamic and interactive platform for presenting information. Its ability to integrate multimedia elements supports a more engaging learning experience, which can help manage intrinsic cognitive load by breaking down complex concepts into more digestible parts. However, the potential for cognitive overload exists if too much information is presented at once or if the design is not well-structured. To optimize cognitive load, educators must balance the richness of content with clarity and simplicity, ensuring that students can absorb and process information effectively without becoming overwhelmed.

4.1. Characteristics, Advantages, and Disadvantages of PPT Teaching

PPT teaching has distinct characteristics that affect cognitive load, offering both advantages and disadvantages. Its integration of multimedia elements—text, images, animations, and videos—enhances understanding by presenting knowledge diversely, reducing intrinsic cognitive load. For example, animations in math can vividly demonstrate geometric transformations. PPT's dynamic capabilities allow intuitive explanations of abstract concepts, further easing cognitive load. Strong information integration links new and prior knowledge, increasing germane cognitive load. The repeatability of slides supports flexible pacing for individual learning needs. However, poorly designed presentations can cause extraneous cognitive load, requiring careful planning to maximize PPT's benefits.

4.1.1. Advantages

PPT teaching offers advantages like multimedia integration, enhancing understanding through diverse formats. It reduces intrinsic cognitive load by simplifying complex concepts and allows flexible pacing with repeatable slides, catering to individual learning needs and improving comprehension through dynamic, intuitive demonstrations.

1) Integration of Multimedia Elements

PPT can integrate text, images, animations, videos, and other elements. In high school mathematics, for instance, when explaining geometric transformations, animation can be used to demonstrate the processes of translation, rotation, and reflection of shapes. For example, when discussing the rotational symmetry of a square, a PPT animation can clearly show the square coinciding with itself after being rotated by 90˚, 180˚, 270˚, and 360˚. This integration of multimedia elements presents knowledge in multiple forms, enriching the teaching content and reducing intrinsic cognitive load. This is consistent with Mayer's (2001) multimedia learning theory, which posits that multimedia information can enhance learners' understanding by providing multiple forms of representation [9].

2) Dynamic Demonstration

When teaching about the dynamic changes in function graphs, such as the effects of parameter changes on a quadratic function $y = ax^2 + bx + c\left(a \neq 0\right)$, PPT can dynamically demonstrate how the sign and value of a affect the direction and width of the parabola (When $a > 0$, the opening is up, and when $a < 0$, the opening is down.), the value of $|a|$ a determines the width of the opening, how b affects the position of the axis of symmetry $x = -\frac{b}{2a}$, and how c determines the y-intercept. This helps students understand abstract mathematical concepts more intuitively, reducing the difficulty of understanding and, hence, the intrinsic cognitive load.

3) Strong Information Integration

PPT allows for the systematic integration of large amounts of mathematical knowledge, for example, by using hyperlinks to connect different chapters or types of mathematical knowledge. This helps teachers build a comprehensive knowledge system and aids students in associating new learning with prior knowledge, thereby increasing germane cognitive load (Sweller, J. 2023) [10]. For instance, when reviewing algebra in high school mathematics, a teacher can use PPT to link various concepts like numbers and expressions, functions, and sequences, creating a network of hyperlinks that makes it easy to navigate to detailed explanations of each concept.

4) Repeatability

Teachers can easily replay specific slides or animations in PPT, allowing them to re-explain concepts that some students have not yet grasped. This flexibility caters to students' varied learning paces. For example, when explaining the eccentricity of an ellipse in conic sections, a teacher can replay the animation showing the relationship between eccentricity and the shape of the ellipse (from nearly circular when e approaches 0 to very elongated when e approaches 1).

4.1.2. Disadvantages

PPT teaching's disadvantages include the risk of extraneous cognitive load from overly complex or poorly designed presentations. This can overwhelm learners, necessitating careful planning and execution to ensure clarity and effectiveness, preventing distractions, and maintaining focus on essential content.

1) Easily Distracting

If PPT is poorly designed, with overly flashy animations, too much text, or uncoordinated color schemes, it can increase students' extraneous cognitive load. In some high school mathematics classes, PPT slides crowded with text and excessive animations can distract students from focusing on the core content. For example, when explaining the formula for the sum of a sequence, if the PPT slide is filled with unnecessary animated images and too many different colors, students may be attracted to these irrelevant elements rather than understanding the formula derivation. This aligns with Kandel's (2020) findings that poor instructional design can increase extraneous cognitive load and impair learning outcomes [11].

2) Difficulty in Pacing:

The fixed pace of advancing PPT slides may cause teachers to follow the pace of the PPT rather than adjust to students' actual progress, leading some students to fall behind. For example, during a lesson on using vectors to solve solid geometry problems, if the slides are moved too quickly, students may not fully grasp the establishment of vector coordinates and the application of vector operations before the teacher moves on to the next example.

3) Lack of On-the-Spot Interaction

Compared to blackboard teaching, PPT teaching tends to have weaker interaction during the lesson. Teachers may focus more on operating the PPT than interacting with students, reducing eye contact and immediate feedback. For instance, when teaching the concept of monotonicity of functions, a teacher might display the function graph and definition on the PPT without noticing that some students are confused by the term "arbitrary," missing the opportunity to clarify. In contrast, blackboard teaching allows teachers to observe students' reactions and provide timely explanations.

4.2. The Role of PPT Teaching in Different Types of Cognitive Load

PPT teaching plays a crucial role in managing different types of cognitive load. By using multimedia elements effectively, reduces intrinsic cognitive load, making abstract concepts like vectors more intuitive. However, poor design can increase extraneous cognitive load, distracting learners. Conversely, well-structured presentations enhance germane cognitive load, helping students build comprehensive knowledge frameworks.

4.2.1. Intrinsic Cognitive Load

If multimedia elements in PPT are used appropriately, they can help present abstract mathematical knowledge in a more intuitive form, thereby reducing intrinsic cognitive load. For example, when teaching about vectors, using PPT animations to demonstrate vector magnitude and direction helps students understand that a vector can be represented by a directed line segment, with the length representing magnitude and the arrow indicating direction. This is more effective than just verbal explanations or blackboard sketches, reducing the intrinsic cognitive load caused by the abstract nature of the concept. This aligns with Mayer's (2001) multimedia learning theory, which posits that different forms of representation facilitate learners' understanding [9].

4.2.2. Extraneous Cognitive Load

However, if the PPT design is inappropriate—such as containing overly flashy animations, excessive text, or uncoordinated colors—students' extraneous cognitive load may increase. For example, when explaining transformations of trigonometric graphs, if the PPT includes complicated background images and flashing text, students may struggle to concentrate on how the graph changes through translation or stretching. This supports Sweller's (1994) conclusion that poor instructional design increases extraneous cognitive load, affecting learning outcomes.

4.2.3. Germane Cognitive Load

When a PPT effectively demonstrates relationships and rules among different mathematical concepts, such as using a mind map-style slide to show connections among chapters in high school mathematics, it can help students build a comprehensive knowledge framework, thereby increasing germane cognitive load. However, if the PPT content merely lists information without showing logical relationships, it may fail to play this role effectively. For instance, when reviewing the geometry section, if the PPT simply lists various topics in plane and solid geometry without showing how plane geometry underpins solid geometry, or how they relate to spatial reasoning, it cannot adequately help students build a related knowledge system. This approach aligns with Sweller's (1994) suggestion that guiding students to construct a knowledge framework increases germane cognitive load. Additionally, Fahad Alturise (2020) emphasized in Learning and Instruction that presenting knowledge logically is crucial for effective learning [12].

4.3. Impact of Teaching Content

When discussing the impact of blackboard teaching on cognitive load, it's important to consider the varying effects it may have depending on different teaching content and student backgrounds. Here are some factors and considerations:

4.3.1. Abstract vs. Concrete Content

Algebra: Algebra often involves abstract symbols and multiple steps. Blackboard teaching can help by allowing teachers to write and explain each step gradually, enabling students to digest the information as it's presented.

Geometry: Geometry requires visual understanding, and the blackboard can be used to draw and dynamically demonstrate geometric relationships, aiding students in comprehending complex spatial concepts through step-by-step construction.

4.3.2. Complexity

For complex concepts or multi-step reasoning, blackboard teaching allows teachers to adjust the pace and content in real-time based on student feedback, ensuring that students can follow and understand each step.

4.4. Impact of Student Background

Student background significantly impacts learning effectiveness. Blackboard teaching accommodates diverse learning styles by integrating visual aids and verbal explanations. It also supports students with varying prior knowledge through step-by-step guidance. Additionally, clear writing and explanations assist non-native speakers in grasping terminology and concepts more effectively.

4.4.1. Learning Styles

Some students may prefer visual learning, while others rely more on auditory or hands-on approaches. Blackboard teaching can cater to different learning styles by combining visual aids with verbal explanations.

4.4.2. Prior Knowledge

Students' prior knowledge levels affect their understanding of new content. For those with weaker foundations, the step-by-step explanation and immediate feedback of blackboard teaching can help them keep up with the course.

4.4.3. Cultural and Language Background

For non-native speakers, the clear writing and explanation provided in blackboard teaching can aid in understanding terminology and concepts.

4.5. Advantages of Blackboard Teaching

Real-time Interaction: Blackboard teaching allows teachers to adjust content and pace in response to student reactions and questions, reducing extraneous cognitive load.

Incremental Presentation of Information: Presenting information gradually on the blackboard helps students understand and absorb complex concepts step by step, reducing intrinsic cognitive load.

Flexibility: Teachers can freely add, modify, or remove information on the blackboard to accommodate changes during the teaching process.

While blackboard teaching can help manage cognitive load in many situations, its effectiveness also depends on the specific teaching content and student backgrounds. Teachers should flexibly combine blackboard teaching with other methods (such as multimedia tools and interactive activities) based on the course content and students' needs to achieve the best educational outcomes.

5. Research Methods

The research employed classroom observation, student surveys, and performance analysis to assess teaching methods. Observations in high school math classes recorded student engagement and understanding under blackboard and PPT teaching. Surveys captured students' subjective experiences and perceived cognitive load. Performance analysis compared exam scores, revealing differences in understanding basic concepts versus dynamic applications between the two methods.

5.1. Classroom Observation

Observations were made in mathematics classes in multiple high schools, recording students' performance under both blackboard teaching and PPT teaching. This included students' attention levels, participation in class interactions, and their understanding of the material. For example, during a solid geometry lesson taught with blackboard teaching, the teacher drew diagrams on the board to explain how to calculate the surface area of a triangular prism. Most students were observed to attentively follow the teacher's drawing and actively answer questions about each face's area calculation. In another class on functions taught with PPT, students watched the animation of a changing function graph, but some failed to answer questions on the transformation patterns due to distraction. Classroom observation is a common educational research method that has been widely used, such as in Pianta and Hamre's (2009) work on understanding classroom processes through standardized observation [13].

5.2. Student Surveys

Surveys were designed for high school students to gather their subjective experiences with blackboard teaching and PPT teaching, the extent to which these methods helped them understand mathematical concepts, and how they perceived these methods impacted their cognitive load. For instance, questions included: "What advantages do you think blackboard teaching has in helping you understand mathematical concepts?" and "Do you find the animation demonstrations in PPT teaching helpful for learning transformations of function graphs? If so, how? If not, why?" The survey design and analysis referred to DeVellis (2016), which provides guidance on the theory and application of scale development [14].

5.3. Performance Analysis

Students' mathematics exam scores were collected after a period of either blackboard or PPT instruction, analyzing their performance on different topics (e.g., algebra, geometry, functions) to evaluate the impact of each teaching method. For example, two parallel classes in a high school were studied—one primarily using blackboard teaching for functions, and the other using PPT. After one month of instruction, a special test on functions revealed that the blackboard class performed better on basic knowledge, such as function definitions, domains, and ranges, while the PPT class scored higher on questions involving dynamic changes and connections between functions and equations.

6. Research Results

The research results highlight the strengths of both blackboard and PPT teaching methods. Blackboard teaching excels in conveying basic concepts and enhancing logical reasoning, with students scoring higher in fundamental topics and reasoning tasks. Conversely, PPT teaching is more effective for demonstrating dynamic changes and integrating real-life examples, leading to better performance in complex geometry and application-related questions.

6.1. The Effectiveness of Blackboard Teaching

Research indicates that blackboard teaching effectively enhances students' understanding of basic concepts and logical reasoning. By observing the teacher's step-by-step process, students can better grasp foundational ideas and engage more actively in problem-solving, leading to improved academic performance.

6.1.1. In Teaching Basic Concepts

Through classroom observations, it was found that in teaching basic concepts in high school mathematics, such as sets and function domains, blackboard teaching helps students focus more on the key elements of these concepts. For instance, when explaining different ways to represent a set, the teacher writes out the enumeration and descriptive methods along with examples on the blackboard, allowing students to clearly see the process. Survey results indicated that most students found blackboard teaching more helpful in understanding basic concepts, as the teacher's step-by-step writing process gave them sufficient time to think. Performance analysis also showed that students exposed to more blackboard teaching performed better on questions involving fundamental concepts. For example, in a quiz on set concepts, students in the blackboard-taught class scored approximately 10% higher on questions related to set properties and relationships compared to those in the PPT-taught class. (See Table 1)

Table 1. Average score on conceptual questions regarding the properties of set elements and relationships under Blackboard and PPT teaching.

Teaching method	Average scoring rate (Set concept test)	Number of students	Total score
Blackboard	68%	30	2040 (30 68)
PPT	56%	30	1680 (30 56)

6.1.2. In Logical Reasoning

In logical reasoning tasks, such as deriving the general formula for sequences or solving geometric proof problems, the gradual presentation of blackboard teaching showed significant advantages. Students were able to follow the teacher's reasoning step by step, reducing instances of logical leaps. Classroom observations revealed that students were actively engaged in the derivation process when following the steps on the blackboard. For example, in geometric proof problems, the teacher wrote out given conditions, auxiliary constructions, and each reasoning step on the board, while students kept up with the logical flow. Survey results indicated that students believed the blackboard helped them follow the logic more easily. Performance analysis showed that blackboard teaching improved students' accuracy in solving reasoning problems. For instance, in problems involving the derivation of the general formula for a sequence, the accuracy rate in the blackboard-taught class was about 15% higher than in the PPT-taught class. (See Table 2)

Table 2. The test accuracy rate of the derivation of the general formula for a sequence under blackboard and PPT teaching.

Teaching method	Accuracy of Answers (series general term formula derivation test)	Test quantity	Correct number of questions
Blackboard	73%	20	14.6 (approximately 20 73%), assuming an upward rounding of 15
PPT	58%	20	11.6 (approximately 20 58%), assuming an upward rounding of 12

6.2. The Effectiveness of PPT Teaching

PPT teaching excels in illustrating dynamic changes in complex mathematical figures, like slicing or rotating shapes, and incorporating real-life examples through multimedia. This method captures student interest, aids comprehension of abstract concepts, and links math to practical applications, resulting in higher performance on related tests and application-based questions.

6.2.1. In Demonstrating Dynamic Changes in Complex Mathematical Figures

PPT's dynamic presentation features were highly effective in demonstrating the slicing, rotation, and transformation of complex figures, such as those found in solid geometry. Classroom observations showed that students were particularly interested in these dynamic demonstrations and focused intently on the screen. For example, during a lesson on deriving the lateral area of a cylinder, the PPT animation showed the process of unfolding the lateral surface into a rectangle, and students were able to understand the relationship between the cylinder's base circumference and the length of the rectangle. Survey results indicated that students found the dynamic demonstrations helpful for understanding the changing relationships between complex shapes. Performance analysis showed that students who were taught with PPT for dynamic figure demonstrations scored better on related topics. In a test involving the interpretation of views and projections of solid geometry figures, the average score of students in the PPT-taught class was about 25% higher compared to those in the blackboard-taught class. (See **Table 3**)

Table 3. Average score of view judgment and projection calculation under Blackboard and PPT teaching.

Teaching method	Scoring rate (Stereogeometry view and projection test)	Number of students	Total score (assuming 1 point per question)
Blackboard	78%	35	273 (35 0.78)
PPT	52%	35	182 (35 0.52)

6.2.2. In Introducing Real-Life Examples

PPT allowed for the integration of real-life examples through images, videos, and other media, which helped students relate mathematical concepts to real-world scenarios. For example, displaying the geometric structures of buildings helped explain solid geometry, or using stock charts helped teach about function trends. Classroom observations indicated that students were more likely to connect mathematical knowledge with practical applications when exposed to these examples. For instance, when teaching trigonometric functions in physics, the teacher inserted a video of a pendulum's motion and linked it to the graph of a sine function, explaining how the displacement varied with time. Students responded positively to seeing how math applied to actual situations, improving their understanding of concepts like periodicity. Survey results confirmed that most students found the inclusion of real-life examples through PPT helpful. Performance analysis showed that students exposed to real-life examples during PPT instruction performed better in application-related questions. In a test on function applications, students in the PPT-taught class scored approximately 18% higher in interpreting problem contexts and modeling functions compared to those in the blackboard-taught class. (See **Table 4**)

Table 4. Scores for functional word test under Blackboard and PPT teaching.

Teaching method	Scoring rate (functional word test)	Number of students	Total score (assuming 1 point per question)
Blackboard	75%	32	240 (32 0.75)
PPT	58%	32	185.6 (32 0.58)

7. Discussion and Recommendations

To optimize high school math teaching, a blend of blackboard and PPT methods is recommended. Blackboard excels in explaining basic concepts and logical reasoning, while PPT effectively visualizes complex figures and real-life applications. Teachers should refine blackboard skills for clarity and pace, and design concise, relevant PPT content to enhance learning.

7.1. Combining the Two Teaching Methods

Both blackboard and PPT teaching have their strengths and weaknesses. They should be used in a complementary manner. In high school mathematics classrooms, blackboard teaching is more suitable for explaining basic concepts and logical reasoning, providing a solid foundation for knowledge construction. In contrast, PPT is more effective for visualizing complex figures and introducing real-life scenarios. For example, when teaching conic sections, blackboard can be used to derive the standard equations of ellipses, hyperbolas, and parabolas in detail, while PPT can demonstrate practical applications in areas like aerospace trajectory design or optical reflection properties (e.g., the focusing properties of a parabola).

7.2. Optimizing Teaching Strategies

Optimizing teaching strategies involves enhancing both blackboard and PPT methods. For blackboard teaching, educators should focus on clarity, pacing, and using colors to emphasize key points, adapting to student reactions. In PPT teaching, the emphasis should be on concise content, relevant images, and simple animations to minimize cognitive load. This approach ensures effective communication of concepts and engages students in a meaningful learning experience.

7.2.1. For Blackboard Teaching

Teachers should continuously improve their blackboard design skills, ensuring clarity and emphasis on key points. It is also important to match the writing pace with students' thinking speed. For example, when teaching mathematical induction, teachers can clearly outline the three steps—basis, induction hypothesis, and induction step—on different sections of the blackboard, using different colors for key points. Adjustments should be made based on students' expressions and reactions to ensure they follow along.

7.2.2. For PPT Teaching

Teachers should carefully design PPT content to avoid excessive irrelevant information and flashy animations. Text in PPT should be concise, and images and animations must be closely related to the teaching content to reduce extraneous cognitive load. For example, in a PPT on sequences, avoid cramming in too much explanatory text; instead, use succinct language to summarize key points, complemented by simple animations to illustrate concepts, such as showing the constant difference between terms in an arithmetic sequence.

8. Conclusions

The research, grounded in cognitive load theory, provides valuable insights into how blackboard teaching and PowerPoint (PPT) teaching distinctly affect students' cognitive load in high school mathematics classrooms, thereby influencing overall teaching effectiveness. Blackboard teaching proves particularly beneficial in situations that require the explanation of foundational concepts and the guidance of logical reasoning processes. By allowing for a step-by-step approach, helps to minimize students' cognitive load, enabling them to better absorb and understand the material, ultimately enhancing learning outcomes.

Conversely, PPT teaching offers significant advantages in scenarios where the visualization of dynamic changes in complex figures is necessary. It excels in integrating multimedia elements to illustrate real-life examples, making abstract concepts more relatable and engaging for students. This method can capture students' attention and facilitate a deeper understanding of the material by connecting theoretical concepts to practical applications.

To maximize the benefits of both approaches, educators should aim to effectively combine blackboard and PPT teaching methods. By strategically optimizing their respective strengths, teachers can better allocate students' cognitive resources, ensuring that cognitive load is managed efficiently. This balanced approach not only improves the quality of high school mathematics instruction but also fosters a more conducive learning environment. As a result, students are more likely to achieve a comprehensive understanding of mathematical concepts and develop a stronger foundation for future learning in mathematics.

Conflicts of Interest

The authors declare no conflicts of interest.

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