RESEARCH ON HIGH SCHOOL MATHEMATICS EXPERIMENT AND VISUAL TEACHING BASED ON GGB

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ABSTRACT

In the context of mathematical literacy and new media teaching as the current hot topics in teaching, this paper is based on the general high school mathematics curriculum and focuses on the teaching application of GGB software in high school mathematics experimental classes. It studies the high-efficiency visualization teaching content in the new curriculum and the expected effects of integrating GGB into high school mathematics experiments. It aims to improve the high school mathematics class better and provides course implementation strategies, offering ideas and methods for GGB visualization courses in various teaching applications.

Keywords: GGB; Mathematical experiment; Visual teaching; High school mathematics curriculum; Core competencies.

OVERVIEW AND ADVANTAGES OF GGB SOFTWARE

The "National Curriculum Standards for High School Mathematics (2017 Edition, 2020 Revision)" clearly states [1] that we should attach importance to the combination of modern information technology and mathematics teaching. This requires further strengthening the deep integration of information technology and mathematics teaching. GGB is a very practical and comprehensive mathematical software, and it also have a widely uses in teaching. It contains many tools modules such as geometry, algebra, tables, graphics, statistics, and calculus. It has strong interactivity, simple interface, free materials, and easy to operate and learn. It is suitable for visual teaching in mathematics classrooms and provides a good environment support for students to experience and perceive mathematics. By utilizing the powerful functions of GGB, students can have a more intuitive understanding of abstract knowledge, improve learning efficiency and interest, and promote their comprehensive development. Teachers can use the drawing tools which provided in the toolbar to drawing by manipulate the mouse in the geometric directly. They can also input algebraic expressions directly in the GGB command area to generate corresponding function images, achieving visual teaching. Visualization refers to the theory, methods, and techniques of using computer graphics and image processing techniques to convert data into graphics or images that can be interacted with[2].

Mathematical visualization is the process of presenting abstract mathematical learning objects (concepts, principles, structural relationships, methods of thinking, etc.) in visible representation forms (graphics, images, animations, etc.) in a clear and straightforward manner, allowing people to have a visual, intuitive, and holistic understanding and comprehension of the mathematical learning objects[3]. Further guide students to gradually delve from intuitive perception to mathematical abstract thinking. The implementation of this process relies on various visualization tools and software.

Visual teaching based on GGB refers to the use of GGB for visual design of teaching content and its application in actual course teaching. With the help of GGB software, teachers can create different visual teaching environments to enhance the fun of course content, make the classroom atmosphere more active, and significantly increase student participation[4]. Enable students to have a more intuitive experience of graphic changes, enhance their thinking of combining numbers and shapes, deepen their understanding of concepts, better comprehend and apply mathematical knowledge, and lay a foundation for subsequent learning. And in the integration of GGB and high school mathematics teaching, the following three principles must be strictly followed[5]: the principle of adaptability, not all content is applicable to GGB software for teaching, and its necessity should be fully considered to avoid making simple teaching content cumbersome; The principle of subjectivity, in the teaching process, should take students as the main body, mobilize their enthusiasm and participation, give full play to the advantages of GGB software, and stimulate their enthusiasm; Suggest the principle of dynamism, and when using GGB to create videos, ensure that the production interface is simple and beautiful to avoid distracting students' attention due to excessive complexity.

Analysis of high school mathematics content and visual teaching based on GGB

The high school mathematics curriculum can be divided into four main lines: functions, geometry and algebra, probability and statistics, and mathematical exploration and modeling activities. The knowledge of each main line can be assisted by information technology in teaching. In teaching, GGB is used for visual teaching design for efficient explanation. The following are the applications in some main modules:

Functions and graphs

Function is one of the core concepts in high school mathematics, and the new curriculum emphasizes studying the properties of functions through function graphs. During the teaching process, using GGB to draw graphs of various functions, inputting algebraic expressions into the instruction bar can automatically generate corresponding graphs, including linear functions, quadratic functions, trigonometric functions, etc. Students can understand the properties of a function, such as slope, zeros, vertices, periodicity, monotonicity, etc., by observing the changes in the function graph. In addition, GGB also supports dynamic adjustment of function parameters, allowing students to observe the impact of parameter changes on function graphs in real time. Enable students to have a deeper understanding of the definition, properties, and applications of functions in practical problems.

Geometric drawing and transformation

The new curriculum standard divides geometry content into two parts: plane geometry and solid geometry, including the properties of basic geometric shapes, geometric transformations (such as translation, rotation, symmetry, etc.), and the understanding of spatial geometry. Intended to cultivate students' spatial imagination and geometric intuition abilities. Plane geometry focuses on the properties and transformations of shapes in two-dimensional space, while solid geometry extends to three-dimensional space. GGB can assist students in drawing various geometric elements such as points, lines, faces, polygons, conic sections, etc. in both planar and three-dimensional spaces. Through dynamic operations, students can intuitively observe and understand the effects of geometric transformations such as translation, rotation, and symmetry, deepening their understanding of geometric concepts.

Algebraic operations and equation solving

Algebra is the fundamental language of mathematics, including real numbers, complex numbers, algebraic expressions, equations (such as linear equations, quadratic equations, fractional equations, irrational equations, etc.), and the basic concepts and operating rules of inequalities. Students need to master basic skills such as simplifying algebraic expressions, solving equations, and solving inequalities. The new curriculum standards strengthen students' basic knowledge and computational abilities in algebra through modules on algebraic operations and equation solving. GGB supports algebraic operations and equation solving functions, allowing students to directly input algebraic expressions and equations for calculation and solution. By dynamically adjusting the parameters or variable values in the equation, students can observe the changes in the solution of the equation and deepen their understanding of algebraic concepts and equation solving methods.

Analytical geometry

Analytic geometry is a bridge connecting algebra and geometry, mainly including equations for lines and circles, conic equations and their properties, etc. Students need to master the method of listing equations based on conditions and solving them, as well as the ability to use equations to study geometric properties. The new curriculum standard strengthens students' algebraic operation ability and geometric intuition ability through the analysis of geometric modules. In the Analytic Geometry module, GGB can help students draw conic sections such as lines and circles, ellipses, hyperbolas, and parabolas, and demonstrate their standard equations and geometric properties. By dynamically adjusting parameters or positions, students can intuitively understand the formation and variation process of conic sections, as well as their positional relationship with straight lines.

Calculus

Calculus is the foundation of advanced mathematics, including the definition, calculation, and application of derivatives (such as finding tangent slopes, monotonicity of functions, extremum, etc.), as well as the concept, calculation, and application of definite integrals. The new curriculum standard introduces preliminary knowledge of calculus as an elective content in high school, aiming to cultivate students' limit thinking, derivative concepts, and integral thinking. GGB has the function of calculus, which can calculate the derivatives, integrals, and limits of functions. Students can understand the concept of derivatives by observing the tangent slope of the function graph, and observe changes in the integral value by dynamically adjusting the integration interval. This is very helpful for learning basic calculus knowledge such as derivative applications, integral calculations, and limit concepts.

2.6 Data statistics and analysis

The new curriculum emphasizes the connection between mathematics and reality, and the collection, organization, description, and analysis of data are extremely important. Students need to learn how to use statistical charts to display data, understand random events and their probabilities, and be able to perform simple probability calculations. GGB also has data statistics and analysis functions, which can generate statistical charts such as bar charts, pie charts, and scatter plots. Students can use these functions to organize and analyze actual data, understand the distribution patterns and trends of data, and improve their data processing abilities.

Integrating GGB into high school mathematics teaching in different aspects

In terms of teacher teaching

Integrating GGB into high school mathematics teaching provides great convenience for teachers, while expanding the depth and breadth of teaching. For example, when exploring the graphs and properties of quadratic functions, we use the graphical drawing function of GGB to easily draw parabolas, and by dragging vertices or focal points, observe the changes in the image in real time, and intuitively understand key elements such as opening direction, vertex coordinates, and symmetry axis. In the field of analytic geometry, when studying the positional relationship between lines and circles, GGB's intersection tool can instantly display the intersection points of the two shapes. Combined with distance formulas and angle measurements, students can intuitively experience the entire process from separation to tangency and then to intersection. For complex composite functions, such as the combination of exponential and logarithmic functions, GGB's composite function calculator and image overlay function not only demonstrate the generation process of composite function images, but also help students understand the monotonicity, extremum, and other properties of composite functions through parameter adjustment. When comparing the effects of different base numbers of logarithmic functions on growth rates, a unified range of independent variable changes is set, and the dynamic chart function of GGB is used to visually compare the growth rates of function values under different base numbers, in order to deeply understand the characteristics of logarithmic growth. In the study of solid geometry, students can freely rotate, scale, and observe geometric shapes such as rectangular prisms and spheres through the three-dimensional models constructed by GGB. They can even dynamically demonstrate the process of cutting cross-sections, enhance spatial imagination, and deepen their understanding of geometric properties. In the learning of arithmetic sequences or proportional sequences, GGB can be used to draw the graph of the sequence. By dragging the slider to change the parameters such as the first term, tolerance, or common ratio of the sequence, students can observe the changes in the sequence graph in real time, thereby deepening their understanding of the properties of the sequence and achieving visual teaching.

In terms of student development

Using GGB to implement mathematical visualization teaching not only allows students to better understand mathematical knowledge, but also greatly helps with overall mathematics teaching. It can meet the needs of various high school mathematics teaching and make great improvements in student cultivation, which is in line with the current national direction for student cultivation and emphasizes the improvement of various mathematical thinking methods.

(1) The idea of combining numbers and shapes

The idea of combining numbers and shapes refers to better expressing abstract mathematical language and quantitative relationships through intuitive graphics. The "combination of numbers and shapes" and "dynamic demonstration" functions of GGB can visually present abstract static geometric shapes to students in a dynamically changing way, cultivating students' spatial imagination literacy [6].

When exploring the relationship between quadratic functions and parabolas, students are no longer satisfied with just memorizing formulas and image features, but use GGB to dynamically draw parabolas and observe image changes in real time by adjusting coefficients a, b, and c. This intuitive feeling allowed them to deeply understand the close relationship between the opening

direction, vertex positions, and coefficients of quadratic functions, achieving a leap from abstract algebraic expressions to concrete geometric images. GGB also plays an important role in solving linear programming problems. Students can draw the feasible domain corresponding to the inequality system, observe the intersection point changes with the feasible domain by dragging the contour lines of the objective function, and find the optimal solution. In this process, students not only master the basic methods of linear programming, but more importantly, they learn how to transform the algebraic form of inequalities into the geometric form of planar regions, and then solve problems through geometric analysis, truly achieving the combination of numbers and shapes. In the study of complex numbers, GGB helps students connect algebraic concepts such as modulus and argument of complex numbers with intuitive properties such as length and angle in geometric images by drawing complex planes and demonstrating the correspondence between complex numbers and vectors. By observing the geometric transformations such as rotation and scaling caused by complex multiplication, students have a profound understanding of the geometric significance of complex operations, thus achieving a seamless transition from algebraic operations to geometric transformations, further consolidating the idea of combining numbers and shapes.

(2) Returning to thought
The concept of transformation refers to the process of transforming difficult problems into familiar and easily solvable ones. This method can turn difficulties into ease and abstract concepts into intuitions.

The exploration of the summation and general formula of a sequence can actually be attributed to the process of splitting, reassembling, or constructing a new sequence. With the help of GGB software, students can intuitively feel the relationship between items in a sequence, change the items in the sequence or adjust the general formula of the sequence by dragging the slider, and dynamically demonstrate and derive the properties of the sequence. Let students deeply understand that the process of summing up is actually a combination problem of transforming a sequence into a sum of arithmetic sequences and a sum of constant sequences. When studying volume and cross-sectional area in solid geometry, GGB's 3D cutting tool can be used. By selecting the cutting surface and adjusting the position and direction according to the question or teaching needs, students can intuitively see the process of geometric objects being cut into different parts. At the same time, GGB will calculate and display the volume and cross-sectional area of each part in real time, which helps students to have a deeper understanding of the calculation methods of volume and cross-sectional area. And by demonstrating the transformation of complex solid geometry problems into multiple simple geometric problems, it deepens students' understanding and application of the concept of transformation.

(3) Classify and discuss ideas
The idea of classified discussion is to decompose the research problem into multiple basic problems based on the characteristics and requirements of the topic, and solve them one by one. This method can cultivate students' meticulous and organized thinking.

When exploring the relationship between the distribution of roots of quadratic equations and discriminant equations, using GGB software can achieve visual teaching to a greater extent. Teachers guide students to use GGB to draw quadratic function graphs with different coefficients,

which correspond to different values of the discriminant equation (Δ), including Δ>0 (two unequal real roots), Δ=0 (two equal real roots), and Δ<0 (no real roots). By dynamically adjusting the coefficients of the quadratic function, students can intuitively see the changes in the intersection point between the image and the x-axis, and better understand the relationship between the values of the discriminant and the number of roots. By discussing different situations, students can cultivate the idea of classified discussion and improve their logical reasoning skills.

Students' comprehensive application of mathematical knowledge

After mastering the basic knowledge and thinking methods, it is more important to flexibly respond to comprehensive application problems. To achieve theoretical guidance for practice, practical verification of theory, and learning from practice.

When exploring the displacement variation law of an object in harmonic motion over time, students can combine the image transformation and properties of sine and cosine functions with physical background, and use GGB for simulation experiments to achieve a close combination of abstract mathematical concepts and practical applications. Students can use GGB's dynamic drawing function to draw basic sine and cosine function images, and then observe in real time how the function images change by dragging the slider, inputting parameter values, and other methods. There are also applications of trigonometric functions in solving practical problems, especially in measuring height. The use of GGB software can better promote the integration of theory and practice. For example, if there is a certain distance between a mountain peak and the observer in the question, trigonometric functions need to be used to calculate the height of the mountain peak. In GGB, we can draw simulated scenes, including mountain peaks, observers, and a line of sight from the observer to the top of the mountain peak. Use GGB's measurement tool to mark the angle between the line of sight and the ground (i.e. elevation angle), as well as the distance from the observer to the bottom of the mountain peak. Guide students to understand how to use trigonometric functions to establish mathematical models and transform practical problems into mathematical equations. Students can adjust the parameters in GGB, such as elevation angle and horizontal distance, to observe the real-time changes in the calculation results of mountain peak height, thereby gaining a profound understanding of the application of mathematical formulas in solving practical problems. This combination of learning and practice helps to enhance students' core mathematical literacy, as well as cultivate their innovative thinking and problem-solving abilities.

Visual teaching strategy for high school mathematics experiments based on GGB

When using GGB software for mathematics teaching, teachers need to develop appropriate teaching strategies in order to better integrate course content, fully leverage the advantages of GGB software to improve students' learning efficiency, and enhance their confidence in learning mathematics[7].

Creating visual teaching scenarios using GGB

Effective mathematical experiments are crucial for teaching students. When designing mathematical experiments, targeted and purposeful approaches should be taken. GGB can create intuitive experimental scenarios, simulate teaching experiment related processes, increase the fun of the course, make the classroom atmosphere more active, and promote students' enthusiasm for learning.

For example, when learning the properties of conic sections, the dynamic drawing function of GGB can be utilized to display real-time changes in the shape of the curve by adjusting the parameters of the conic section, such as eccentricity and focal length. Students can intuitively observe the changes in key elements such as asymptotes, vertices, and focal points of conic sections during this process, thereby gaining a deeper understanding of the geometric properties of conic sections. It can also be combined with GGB's trajectory tracking function to display the motion trajectory of points and lines on conic sections. For example, by tracking the uniform motion of a point on an ellipse, demonstrate the property that the sum of its distances to the two focal points is constant. This type of mathematical experiment that constructs visual contexts of dynamic connections makes abstract analytic geometric concepts vivid and intuitive, enabling students to better grasp the relevant knowledge of conic sections. It also cultivates students' observation, analysis, and induction abilities, effectively enhancing their mathematical core literacy.

Developing high school mathematics visualization teaching based on multivariate representation

Multivariate representation refers to the ability to express and understand the same knowledge point in multiple ways. In mathematics, multivariate representation can include numbers, symbols, graphics, and charts. A single representation form is difficult to construct relevant knowledge meanings, so visual teaching needs to pay attention to the diverse presentation of different representations of the same mathematical object[8]. Through GGB, mathematical knowledge can be simulated, demonstrated, and interpreted, visualizing the process of abstract mathematical concept changes and effectively assisting students in deep learning.

For example, when teaching function properties, the function can be represented through symbolic language, that is, the analytical expression of the function, and input and define the function in GGB. By using graphical representations, GGB can draw real-time graphs of functions, visually displaying the trend of the function changing with the independent variable. Students can observe the increase and decrease of functions, extreme points, etc. from the image, in order to preliminarily judge the monotonicity and maximum value of the function. It is also possible to deepen understanding through descriptive representation, that is, textual language description. Based on the dynamic demonstration of GGB, teachers guide students to describe the characteristics of the function graph in accurate language, such as "the function monotonically increases in the interval [a, b]" or "the function reaches a minimum at x=c. Helping students consolidate the concept of function properties while also enhancing their mathematical expression abilities. GGB also has data table representation, displaying the function values under different independent variable values. Students can further verify and deepen their understanding of function properties by observing the numerical changes in the data table. Through the combination of data tables and graphical charts, students can learn from multiple perspectives and levels, deepen their understanding of the properties of functions through the mutual transformation and complementarity of multiple representations, and improve their mathematical core literacy and problem-solving abilities.

Cultivate innovative thinking through variations of classic questions

How to help students solidly promote teaching effectiveness, understand basic concepts, and master classic problems is extremely important. Teachers can expand and extend typical problems,

transform them, and encourage students to think, cultivating their ability to form good innovative thinking and apply them to other situations.

For example, when it comes to exploring the properties of ellipses, the trajectory tracking, parameter equations, and dynamic transformation functions of GGB can be used to visually demonstrate the process of ellipse generation. Let students try to use geometric construction methods combined with algebraic equations to accurately define ellipses. And the teacher designs a series of progressive variation problems based on the learned content, allowing students to try adjusting the length of the major and minor axes of an ellipse in the algebra area, as well as changing the focus position in the drawing area, and observe their different effects on the ellipse. And teachers can encourage students to innovate and adapt questions, such as exploring the property changes of ellipses rotating around their centers or moving along specific paths. Not only can it deepen students' understanding of the properties of ellipses, but it can also effectively stimulate students' interest in learning, cultivate innovative thinking, and promote the improvement of mathematical core literacy.

CONCLUSION

In summary, the application of GGB in high school mathematics visualization teaching has demonstrated its good role and potential, which is conducive to truly implementing the new textbook design concept, inspiring students' wisdom, stimulating learning interest, and cultivating comprehensive mathematical core literacy. We look forward to more related innovations and practices to provide students with richer and deeper mathematical learning experiences, thereby effectively promoting the high-quality development of high school mathematics teaching.

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