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# The Summary of the Research Direction of GeoGebra in Middle School Mathematics Teaching

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## Abstract

GeoGebra, an emerging software for mathematics teaching, has won several educational software awards in Europe and the United States. In foreign countries, GeoGebra has been widely promoted and applied. Some countries have established specialized institutions of GeoGebra to support the teacher' training, the sharing of teacher's experience and research. At present, many Chinese scholars are studying GeoGebra. In 2011, China established the research institute of GeoGebra, which was the chief research institute of GeoGebra in China. It studies mathematics teaching and learning related to GeoGebra, provides professional training for normal students and front-line teachers, shares successful cases and advanced experiences in mathematics learning and teaching, leads and assists the construction and development of other local research institutes of GeoGebra in China, and promotes collaboration among the local research institutes of GeoGebra in China. This paper reviews and sorts out the existing researches, and finds that the current researches on GeoGebra in middle school mathematics focus on the application of GeoGebra in teaching, the role of GeoGebra in teaching, the problems with the use of GeoGebra, and the suggestions on the use of GeoGebra. Through the summary, it is found that some researches are not in-depth enough. Therefore, this paper points out the future research direction, aiming to better promote further research.

## Keywords

GeoGebra, Mathematics Teaching, Middle School

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## 1. Introduction

The application of information technology is conducive to improving and innovating the teaching methods and provides a new impetus for the development of education. Therefore, the effective use of information technology tools in the teaching process has an important impact on the practical teaching effect. The dynamic teaching software GeoGebra can provide a convenient and effective information technology platform for mathematics, improve teachers' teaching methods, stimulate students' interest in learning, and help students to understand abstract knowledge more vividly and intuitively, thus improving the effect of teaching [1]. In order to identify the next research direction, this paper reviews and sorts out the domestic existing researches.

## 2. The Application of GeoGebra in Middle School Mathematics Teaching

### 2.1. Teaching Links Applicable to GeoGebra

Cao qianqiu pointed out that in the process of teachers' lesson preparation, the GeoGebra could generate accurate and beautiful teaching graphics that were applied in teaching plans and courseware. In the process of teaching, GeoGebra could realize various animation gradation effects through careful design, which saved a lot of time in class and increased the

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efficiency of teachers' teaching [2]. Zhang Zhiyong specifically pointed out that in the generative process of concept, teachers could use GeoGebra to display the intuitive background of the concept, visualize the abstract concept, and use the rich examples to make the concept get "prototype" support, form "the concept intuitive mode", which let students experience the original process of conceptual formation and ensure deep understanding due to the process of conceptual formation. In the discovery process of the proposition, teachers could use GeoGebra to place propositions in the context of the development of mathematics, construct propositional networks in the exploration of propositional sources and flows, and form certain structural schema to help students establish a holistic view of structure, which was conducive to the orderly retrieval and comprehensive integration of knowledge. In the teaching process of problem-solving, teachers could help students to master the characteristics of numbers and graphics, explore the internal logical connection and causal relationship between the known conditions and the problem to be solved, find the way to solve the problem, find out the direction of solving the problem with the help of GeoGebra, and form logical, hierarchical, rigorous and normative expressions, and so on [3].

## 2.2. Teaching Contents Applicable to GeoGebra

At present, many domestic scholars choose a specific knowledge point of middle school and then use GeoGebra to present the occurrence and development process of knowledge point, so as to help students to understand and master the corresponding knowledge point more deeply. The knowledge points mainly focus on the function, the algebra and the geometry, the probability and the statistics.

### 2.2.1. The Function

The GeoGebra makes it easier to study the images and properties of the linear function, inverse proportional function, the quadratic function, piecewise function, the exponential function, logarithmic function, power function, and the trigonometric function. At present, many scholars have made the instructional design for one specific knowledge points mentioned above, and in the instructional design, teachers could draw accurate images in a faster way with the help of GeoGebra, which helped students to explore the nature of the function better. For example, Long Zhengwu believed that it was cumbersome and difficult to make the image of piecewise function by hand or relevant teaching software, however, the "if" command in GeoGebra could easily realize the display and mapping of the piecewise function, and it was beneficial for students to master the overall nature and local nature of the piecewise function [4].

### 2.2.2. The Algebra and the Geometry

Zhang Zhiyong, Qian Wentao and Zhao Jun pointed out that in geometry, GeoGebra could draw points, straight lines, line segments, polygons, vectors, conic curves and images of function, make stereo graphics, support geometric transformation while providing commands as tangent lines, polar lines (or radial lines), regression lines, and so on; in algebra, you could input equations, point coordinates or other commands in the command box of the GeoGebra to realize the changes and calculations of the graphics, and the graphics area displayed synchronously. In addition, it could also deal with "variables", and carry out various algebraic operations conveniently, such as derivation and integration, solving the root of the equation, calculating the area and perimeter of the equation, finding out the maximum and minimum value and inflection point of the function, perform matrix and vector operations, realizing precise operations of large numbers, polynomial factorization and simplifying the expression of function [3, 5]. Li Dan and Pan Biao pointed out that when studying the definition of conic curve, it was possible to make students establish the relationship between graphical representation and symbolic representation by means of the function of the GeoGebra to combine the characteristics of numbers and graphics and the function of synchronizing transformations in geometry and algebra [6].

### 2.2.3. The Probability and the Statistics

Xu Minxia pointed out that random simulation was an effective way to solve the probability problem. Using the simulation method, we could estimate the probability and solve the related practical problems. GeoGebra was just about to well simulate the problem situation and enable students to learn the knowledge related to the probability better. For example, in learning classical probability, teachers could use GeoGebra to simulate coin-tossing experiments, let students experience a process, in which the frequency gradually stabilizes near a constant as the number of experiments increased. This exploration process would help students to understand the relationship between frequency and probability, and the significance of random phenomena and probabilities. She also pointed out that it was also very important in today's information society to collect and analyze data, learn to obtain valuable information in the data and provide references for decision-making, and GeoGebra software could realize data processing. For example, the comparison table of the number of cups of hot tea sold in the commissary for 6 days and the temperature of the day was known, predicted the number of cups of hot tea that the commissary sold at the certain temperature. In solving this problem, you could input data in the tabular area of the GeoGebra, select and generate a point column, and

then used “the polynomial regression ”command to fit the function, according to the fitting function to predict the number of hot tea sold by the commissary at the certain temperature, at the same time, the students experienced the process of data processing in the process of inquiry and it helped students to understand the significance of statistics [7].

# 3. The Function of GeoGebra in Middle School Mathematics Teaching

## 3.1. Improving Students' Interest in Learning

Chen Chao and Liu Huixuan pointed out that the integrable ware produced by GeoGebra was dynamic and scientific, which could make highly abstract knowledge become concrete, boring knowledge become interesting, and stimulate learners' interest and motivation in learning mathematics [8, 9]. Jin Feifei and Hou Yan pointed out that GeoGebra could show vivid ideas for solving problems, thus enhancing students' interest in learning. For example, when demonstrating the ideas of solving similar triangles, teachers could use the dynamic control slider in GeoGebra to skillfully construct a triangle, so that students could vividly see the proportional relationship in similar triangles [10]. Huang Chenlu and Zhang Weizhong pointed out that using GeoGebra could draw accurate images in a short time to achieve a better presentation effect, thus stimulating students' interest in learning. For example in learning image and the properties of the quadratic function, you could use the slider in GeoGebra to drag a, b, c, or right-click on the slider to click to start the animation, so that students could intuitively see a, b, c change the opening direction of image, the opening size of the image, and the axis of symmetry of the image, the number of roots. It was conducive for students to deeply realize that the relationship between the change of parameter and the image, and the relationship between the discriminant b2-4ac and the number of roots of quadratic functions [11].

## 3.2. Enhancing Students' Practical Ability to Solve Problems

Jin Feifei, Hou Yan and Pan Junchun pointed out that the use of GeoGebra has increased the chances for students to have a try, do, and use hands and brains, so that students' ability to acquire direct perceptual knowledge was enhanced, and knowledge was explored independently through hands-on operation, which could maximize the intuitive initiative, produce bold conjecture and innovation, so as to cultivate students' hands-on ability to solve problems [10, 12].

## 3.3. Improving Students' Mathematical Thinking Ability

Li Dan, Pan Biao, Jin Feifei and Hou Yan pointed out that GeoGebra could use graphics to present abstract mathematical theory to people in a vivid and intuitive way to help understand and memorize abstract mathematical content, thus inspiring students' mathematical thinking [6, 10]. Zhang Zhiyong and Long Zhengwu pointed out that GeoGebra could penetrate into mathematics discipline to help students understand the essence of mathematics and promote the development of mathematical thinking to a higher level. For example, in order to promote the development of students' statistical thinking, when teaching the content of linear regression analysis, teachers could use the tabular area of GeoGebra to carry out relevant statistical calculation and analysis conveniently and quickly, which helped to focus students' attention on the theoretical and practical meaning of the regression coefficient, namely the understanding and mastery of the principle, rather than the difficulty of implementing the calculation [3, 4].

## 3.4. Deepening Students' Understanding of Mathematical Knowledge Through Multiple Representations of Knowledge

Zhang Zhiyong, Li Dan and Pan Biao pointed out that students could have multiple internal representations or external representations for a certain concept or proposition, and each representation would deepen the students' understanding of mathematics. However, when exposed to new knowledge, the various representations of knowledge established by students were loose and couldn't be converted or translated between representations within the system or between representations. The GeoGebra could provide the students with the “multivariate contact characterization” learning environment, form an effective understanding channel between the symbol language and the tables and the images, and give play to its multiple representational functions, make abstract mathematical knowledge become intuitive, reflect “The math is clear, natural, and logical.”, so as to deepen the understanding of the students' knowledge of mathematics. For example, when teaching the definition of conic curve, teachers could enable students to establish the relationship between graphical representation and symbolic representation by means of the function of the GeoGebra to combine digital and graphical feature and the function of synchronous transformations, so as to organically integrate multiple representations and enable students to form internal representations with rich connections, which was conducive to deepening students' understanding of mathematical knowledge [3, 6].

### 3.5. Reducing the Burden on Teachers to Display Teaching Contents While Improving the Efficiency of Teaching

Li Dan, Pan Biao, and Pan Junchun pointed out that GeoGebra could complete the function of geometer sketchpad, simplify the operation process significantly, save time, and it helped to overcome the time-consuming and laborious shortcomings when teachers used teaching software. For example, in terms of function curve, probability statistics and dynamic demonstration, it reduced the burden on teachers to display teaching contents, improved the accuracy of teaching contents, and made the effect of teaching get twice the result with half the effort [6, 12].

## 4. Problems with the Use of GeoGebra

Bao Keyuan pointed out that the GeoGebra had poor text performance, for example, the characters were too small and the format was not rich. There was no common graphic tool library in middle school, the drawing was inconvenient, the graphics were rough, and the colors were not bright [13]. Li Dan, Pan Biao and Jin Xian pointed out that there were still many aspects of GeoGebra that need to be improved, such as adding paintbrush functions to draw free curves, increasing the filling function, improving the data processing function (currently could only do simple data processing and established the pre-fitting function), simplifying the production of 3D graphics, and adding more shortcuts (such as the display or hiding of images and texts) [6, 14]. Wang Yanping and Zhou Ming pointed out that each window of GeoGebra was independent and couldn't be linked with other windows. Therefore, teachers or students had to manually open each page one by one during teaching, which was rather tedious. Moreover, under the interface of GeoGebra, graphics and texts could only be displayed in the drawing area without boundaries, causing the confusion and untidiness of the interface [1, 15].

Wang Yanping pointed out that some teachers relied too much on teaching media and the content of the blackboard was little, resulting in students couldn't clearly distinguish the main points of the knowledge that they had learned and didn't have a deep understanding of knowledge [1]. Liu Huixuan and Deng Zhenzhen pointed out that some teachers were not actively using computer software to assist teaching. They believed that they would design courseware very slowly with GeoGebra, which was not as fast as preparing lessons with traditional teaching methods, and it would make the discipline of the classroom difficult to manage and affect normal teaching progress. In addition, some parents believed that students' computer operation was not good for eyesight, and they gave children an excuse to play computer [9, 16].

## 5. Recommendations for Using GeoGebra

In order to promote the application of GeoGebra in middle school mathematics teaching, Liu Huixuan and Deng Zhenzhen believed that teachers and parents could change the understanding of GeoGebra in teaching from the perspective of updating teachers' awareness and raising parents' awareness [9, 16]. Wang Yanping pointed out that provinces and cities should carry out distance education training, field visits and seminars, so as to strengthen the training of teachers' professional literacy [1].

In terms of the operation of the software, Wang Yanping pointed out that a set of complete and specific teaching resources should be developed, including the introduction of tools, the methods of operation and case analysis, which were helpful for teachers to quickly master the basic functions of the GeoGebra and the methods of making courseware and effectively help teachers to assist mathematics teaching. It was necessary to set up a knowledge exchange and resource sharing platform, which was conducive to mutual learning and learn from each other [1]. Du Juan, Li Lei, and Bi Weina pointed out that teachers should familiarize students with some basic operations of GeoGebra so that students could concentrate on the study of mathematics rather than the study of software. Before class, students should install GeoGebra, QQ group, the cloud disk and the learning task list on mobile phones [17, 18].

In terms of the functional use of the software, Li Hui, Gao Yuan, and Jiang Jianguo pointed out that teachers should put the “color marking method” through the teaching activities and make use of GeoGebra to make pictures with color characteristics to enhance students' visual sensitivity and improve the effect of teaching. In teaching, teachers should be good at making use of the operation of GeoGebra to highlight the changes of graphics, such as using GeoGebra to decompose and combine graphics, scale down and scale up graphics, translate and rotate graphics, and so on, and attract students' attention with changing stimuli, thus obtaining a proof step or the inspiration of solving the problem; when using the “slider” function in GeoGebra to depict graphical symmetry, congruence, and rotating graphics, teachers should consider the eye's gaze amplitude and the different distribution of the left and right, so as to limit the range of the “slider”, for example, the distance between two symmetrical figures should not be too large, and the speed of rotation should not be too fast; teachers should be good at creating an unforgettable learning environment with the help of GeoGebra, such as giving students more opportunities to complete research

projects independently or cooperatively, thus enhancing students' semantic and episodic memory [19, 20].

In teaching, Bao Keyuan, Du Juan, Li Lei, and Bi Weina pointed out that teachers needed to make full preparations for the mathematical objects involved in using the GeoGebra, including the objects that may be used in teaching and students' communication. After the relevant GeoGebra courseware was ready, it could be distributed to students through the QQ group and the cloud disk. Then students used the courseware to study, explore and consolidate relevant knowledge points in the "extracurricular" environment, which complemented the learning in the classroom [13, 17, 18]. In addition, Wang Yanping and Bao Keyuan pointed out that the teaching software should be chosen according to the characteristics of the teaching content; the presentation of teaching integrable ware should be consistent with the teaching material, which shouldn't confuse students; in teaching, GeoGebra should be combined with other teaching software to give full play to their respective advantages [1, 13]. Song Kai pointed out that when using GeoGebra to assist teaching, students should be properly involved in the process of making courseware with GeoGebra so that they could deepen their understanding and memory of knowledge in the course of making courseware [21].

Zhou Ming pointed out that in the future, GGBBook could be used to design dynamic electronic textbooks. At that time, all the text and formulas could be placed on the left side of the interface of GGBBook and all images and charts were located on the right side of the interface of the GGBBook, which couldn't only realize synchronous changes of images and data, but also made up for the confusion of the interface of GeoGebra. GGBBook also supported switching back and forth among multiple pages, which saved a lot of unnecessary trouble. He also pointed out that the GeoGebra could be installed on a tablet computer, which would make it more convenient for students to carry and would give students a more realistic experience with a touch screen instead of a mouse. At the same time, in places with wireless networks, students could interact with teachers and peers, express opinions, which contributed to improving students' interest and efficiency in learning [15].

## 6. Conclusion

It can be seen from the analysis above that the current researches on GeoGebra in middle school mathematics focus on the application of GeoGebra in teaching, the role of GeoGebra in teaching, the problems with the use of GeoGebra, and the suggestions on the use of GeoGebra. For the application of GeoGebra in middle school mathematics teaching, scholars mainly use GeoGebra to carry on drawing, algebraic calculation and simulate random experiment, and illustrate it through specific teaching cases. For the role of GeoGebra in teaching, scholars mainly study the positive impact of using GeoGebra on students, as well as the positive impact on teachers and the effect of teaching. For the problems with the use of GeoGebra, current researches mainly focus on the functions of GeoGebra, and some scholars also study whether the use of GeoGebra by teachers is reasonable. For suggestions on the use of GeoGebra, the current researches are more extensive. They not only give suggestions on the promotion, operation and functional use of GeoGebra but also give suggestions on the use of GeoGebra in teaching, the future development direction of GeoGebra.

It can be seen from the literature that some studies are not deep enough, and there are two prominent problems: one is the low utilization rate of GeoGebra in China, and it has not been widely promoted and applied in China. Even if there are, most of the researches are given by the master of education at the school to give specific teaching cases for a specific knowledge point, and few front-line teachers study the application of GeoGebra in teaching. The other is when teachers use the GeoGebra in class, the discipline of the classroom will be chaotic and the teachers will be difficult to manage. Although the above problems have been recognized and mentioned by some researchers, at present few people have done more in-depth research from the above-mentioned angles, resulting in that the advantages of GeoGebra in mathematics teaching are not given play to, and teachers and students have no access to touch better teaching and learning tools.

Therefore, it is necessary to strengthen the research in the following two aspects in the future: one is the specific research on the promotion and application of the GeoGebra. The other is how the teacher can organize the students to better use the GeoGebra to study. Only by solving these two problems can we make better use of GeoGebra to help teachers' teaching and students' learning.

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