

# Strategies and Challenges of Game-based Teaching in Geometry for Junior High School Mathematics Classrooms

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**Abstract.** This article focuses on the teaching of geometry in junior high school mathematics classrooms, aiming to address the issue that students find it difficult to actively participate in traditional geometry teaching and thoroughly understand the knowledge. Firstly, based on the advocacy of gamified teaching in the "Compulsory Education Mathematics Curriculum Standards (2022 Edition)" and a review of domestic and international research, this paper summarizes the current research and development status of gamification in geometry teaching. The review finds that current research lacks systematic integration of geometric gamification strategies. Then, the core issues are analyzed, with the main problems focusing on the insufficient compatibility between games and knowledge points, the predicament of classroom management, and the lack of gamified teaching literacy among teachers. Based on the above problems, optimization countermeasures are proposed, namely, constructing a teaching design that precisely matches "knowledge points - games", optimizing the classroom organization model of hierarchical division of labor, and establishing a systematic teacher training system to form a systematic strategy, providing strategic support and teacher cultivation paths for the game-based teaching of junior high school geometry.

## 1 Introduction

Junior high school geometry is a key content for cultivating students' spatial concepts and logical reasoning abilities. However, the traditional teaching mode of explaining abstract concepts and mechanical problem-solving training has led to nearly half of the students having a fear of learning geometry [1]. The "Compulsory Education Mathematics Curriculum Standards (2022 Edition)" points out that primary school mathematics teaching should focus on interest and exploration, advocating the stimulation of students' learning interest through forms such as mathematics games, and promoting their active participation and positive thinking. Under the advancement of educational technology, gamified teaching, as an innovative model, is becoming an important means to enhance students' interest and efficiency in learning. Especially in the teaching of geometric concepts in junior high school

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mathematics, its interactivity and interest can effectively stimulate students' learning motivation and help them deeply understand and master geometric concepts.

With the gradual popularization of the concept of gamification, many scholars, based on the teaching needs of geometry, have studied and designed relevant gamification teaching strategies. Lu Shurong developed a five-step gamified teaching model: concept introduction, process learning, concept testing, learning evaluation, and after-class homework. Taking the content of recognizing triangles as an example, through gamified teaching designs such as model building, quick questioning and answering, and creative display, it stimulates students' creativity and imagination, and deepens their understanding and application of the geometric concept of triangles [2]. Shi Xuehui emphasizes gamified situational teaching, making abstract problems concrete. By constructing scenarios, it stimulates students' associations and encourages them to actively analyze problems and explore solutions [3]. For instance, when teaching the Pythagorean theorem, he created a "rolling ladder" life scenario, which caters to the relatively weak abstract thinking and spatial cognition of junior high school students, helping them extract mathematical concepts from daily scenarios and reducing the difficulty of understanding. When teaching "Rotation of Figures", by showing pictures of windmills, globes, etc., students are asked to observe the commonalities. Then, they are organized to hold hands and rotate counterclockwise once to intuitively feel the positional relationship after rotation. Finally, they are guided to explore the center of rotation to help students systematically master the rotation rules. Silvia's team has found that using virtual reality (VR) to implement gamified geometry teaching, allowing students to learn geometry knowledge in three-dimensional space, can greatly enhance students' participation and activity, which is significantly superior to traditional teaching [4]. Noviana applied the ADDIE development model to explore the feasibility of gamification in geometry teaching. Through comparative experiments, it was found that there was a significant difference in academic performance between the control version and the experimental class. 90% of the students were very interested in the geometry course of VR games [5]. Duggal emphasized that artificial intelligence and machine learning technologies will be applied to gamified teaching to achieve intelligent learning assistance and assessment. For instance, by analyzing students' learning data, the difficulty and content of the game can be automatically adjusted to provide personalized learning suggestions [6].

Existing research recognize the positive value of gamified teaching in junior high school geometry teaching. They unanimously believe that it can effectively solve the core problems of abstract geometry knowledge and weak spatial thinking of students through concrete scenarios and interactive forms. Moreover, it has reached a practical consensus in stimulating learning interest and enhancing spatial cognitive ability, providing a theoretical and case basis for subsequent teaching reforms.

Some research is more focused on the optimization of teaching processes and the adaptation to local classrooms, such as the "five-step" model and the creation of life scenarios, emphasizing the practical integration of games and course knowledge points. Someresearch highlights technological empowerment and personalized design, emphasizing the improvement of teaching accuracy through technological tools and dynamic adjustment mechanisms. The two can complement each other in terms of content design and technological application.

Most of existing research on geometric gamification is mostly confined to the interesting teaching of single figures (such as triangles and circles), rarely connecting geometric proofs with logical reasoning. It mostly focuses on a single knowledge point and lacks a systematic design for the entire educational stage. The transferability of the results is weak. Although there are mature geometry game solutions abroad, most of them are based on foreign textbooks and cognitive systems, making it difficult to adapt to the requirements of the local

"Graphics and Geometry" curriculum standards. Direct use by teachers may lead to connection gaps.

Overall, at present, there is a lack of systematic integration of geometric gamification strategies both at home and abroad, and no effect evaluation has been conducted in response to local teaching needs, which makes it difficult to implement high-quality strategies.

This research aims to establish a strategy system that is adapted to the current situation and the learning conditions of the geometry discipline and students. This research will combine the characteristics of the geometry discipline to develop specialized gamification strategies that focus on students' core competencies such as spatial imagination ability, geometric intuition, and application awareness, achieving a deep integration of geometric knowledge and game forms. Based on the differences in geometric cognition among junior high school students, a hierarchical game scheme is designed to meet the learning needs of students with different abilities. Ultimately, this study aims to provide referential gamification teaching strategies and teacher training programs for junior high school geometry classroom teaching, helping teachers master strategy design and classroom application methods, and ultimately facilitating the effective implementation of geometry gamification teaching in local classrooms.

## **2 The current situation of gamified teaching strategies for geometry in junior high school mathematics classrooms**

### **2.1 The application scope of gamification in geometry teaching in junior high school mathematics classrooms**

In terms of knowledge point coverage, the existing gamified teaching applications are mostly concentrated on the basic geometry modules that are highly intuitive and easy to design games, and the related research is also more abundant, such as the geometric meaning of the number line, the Pythagorean theorem, and the properties of triangles, etc. However, key and difficult modules such as geometric proof and three-dimensional modeling, which are highly abstract and logical, have a relatively narrow coverage due to their high design difficulty.

Most teachers are good at using situational simulation games to assist teaching, with the practical application of geometric knowledge as the core. For instance, in the teaching of the Pythagorean theorem, simulate the measurement of the side lengths of a right triangle by ancient craftsmen. By recreating the application scenarios, students can have hands-on practice and directly experience the geometric principles [7].

Some schools have also integrated high-tech elements into their mathematics and geometry classes and launched digital interactive games. Some scholars have proposed that with the support of information technology, teachers can use teaching tools to design dynamic geometry exploration scenarios, such as Geometer's Sketchpad, GeoGebra, Desmos and other tools [8]. Teachers use modeling software to assist in teaching, making abstract concepts concrete. Students can observe the geometric features of "congruent and similar" by dragging graphics on the screen in dynamic changes.

### **2.2 The current situation of cognition and ability of junior high school mathematics teachers towards geometry gamification teaching**

At present, most teachers still have considerable room for improvement in their understanding and ability of geometry gamification teaching, which is also a major reason why gamification teaching has not been widely promoted in junior high schools. Some scholars have pointed out that some teachers believe that gamified teaching is an entertaining

educational approach and has no practical teaching effect. Teachers believe that gamified teaching is not conducive to a serious classroom atmosphere. Some teachers also pointed out that the integration of teaching and games is rather difficult and it is hard to achieve the expected results. Meanwhile, teachers generally lack theoretical knowledge and practical experience related to gamified teaching, and schools are also unable to provide effective technical support, such as technical tools and drawing software, to create teaching games [9].

### **3 The main problems in the game-based teaching of geometry in junior high school mathematics classrooms**

#### **3.1 Insufficient adaptability to the course knowledge points**

Some scholars have pointed out that some teachers' teaching designs for geometry gamification are "superficial", merely regarding it as a "tool to enhance classroom activity" [7]. At present, many classroom gamification designs are overly formalistic. The game designs do not deeply connect with the essence of geometric knowledge points; they merely simply superimpose game forms with geometric knowledge, failing to carry the cultivation goals of core geometric literacy such as logical reasoning, spatial concepts, and model awareness. During the game process, the teacher's teaching strategy of "emphasizing the result but neglecting the process" effectively boosts the classroom's activity level. However, it fails to guide students to think about the geometric principles behind the result, resulting in students not truly understanding the knowledge points and maintaining a low learning efficiency.

#### **3.2 Classroom management dilemmas in the process of gamified teaching**

In gamified teaching classrooms, some students often remain in a spectator position, merely passively cooperating with operations, and even give up participation due to a sense of frustration. This is because students have different geometric foundations and personality traits. Some students can quickly understand the game rules and actively participate in exploration, while those with weaker foundations and introverted personalities are on the periphery. This leads to the fact that game activities are often dominated by a few active students, and the learning outcomes vary significantly. Gamified teaching has greatly increased the difficulty of classroom management. Due to the "interactivity" and "openness" of geometric games, phenomena such as students operating geometric props in violation of regulations, conflicts caused by excessive competition, and game cheating occur frequently. Teachers have to spend energy and time solving the problem of classroom order, which affects the completion of teaching tasks [10].

#### **3.3 Insufficient teachers' gamification teaching literacy**

Some scholars have found that teachers' gamification teaching literacy is insufficient, their available tools or resources are limited, their time and energy are insufficient, their information technology application ability is inadequate, and their gamification teaching design ability is insufficient. The methods adopted by primary and secondary school teachers for gamified teaching design are usually to imitate and draw on excellent lesson examples or rely on information technology, lacking designs based on students' specific learning conditions and failing to achieve the secondary development of subject knowledge [11]. This leads to excessive formalization and even uniformity of gamified teaching in the classroom. Due to the teacher's failure to set up gamified teaching strategies that closely match the

students' learning conditions and the characteristics of knowledge, the classroom presentation effect was poor, and the content failed to attract students. As a result, the students' learning outcomes were not good.

## **4 Countermeasures for optimizing the gamification of junior high school geometry teaching**

### **4.1 Construct a teaching design plan that precisely matches "knowledge points - games"**

When conducting research projects, teachers should focus on dissecting the essence of geometric knowledge points, clarify core goals such as "figure recognition, theorem derivation, and logical proof" in combination with the curriculum standards, and use them as anchor points for game design, classifying and designing games according to the types of knowledge points. For concept types, use "situational challenge"; for theorem types, use "simulation verification"; and for proof types, use "step-by-step reasoning" to avoid formalization. In terms of teaching design, emphasis is placed on students' subjectivity. For instance, a reasoning section is added to the game rules, requiring students to explain the basis for their operations to ensure that they truly understand the essential logic of the mathematical laws behind the games. Build an integrated "teaching-learning-assessment" model to provide timely and effective evaluations of students' learning outcomes, participation, teamwork, innovative thinking and other abilities [12].

Teachers should make efforts in all aspects, including textbook analysis, teaching design, classroom guidance and evaluation system, to continuously improve the "knowledge point - game" matching system and ensure that games serve teaching.

### **4.2 Optimize the classroom organization model**

In response to possible situations such as winning or losing, comparison, and rejection in gamified teaching classrooms, teachers should pay attention to the different student situations and ensure that students of all cognitive levels have equal opportunities to take on challenges and enjoy the joy of success. In terms of activity arrangement, teachers can design basic, advanced and high-level geometry game tasks, and introduce various roles such as surveyors, recorders and reporters in the group division of labor to ensure that students of different personalities and abilities can all participate in the game activities, and each group member can perform their own duties. At the same time, teachers also need to have the ability to formulate strict game rules, handle game conflicts flexibly, and guide game predicaments [12].

### **4.3 Establish a systematic teacher training system**

Novice teachers focus on the basic design of geometry games and the use of basic tools such as GeoGebra, while backbone teachers focus on the game transformation and innovative design of complex geometry knowledge points. The training adopts a model of "theory + on-site design + demonstration class observation", enabling teachers to master the true methods of gamified teaching through practical operation. At the same time, a geometric game resource library was established, teaching and research groups were formed, cases were exchanged regularly, practical problems were solved, and a development mechanism of continuous research and continuous learning was formed [9].

## 5 Conclusion

This study, through a systematic analysis of the gamification of geometry teaching in junior high school mathematics classrooms, clearly states that gamification teaching is an effective approach to addressing the abstract nature of traditional geometry teaching and stimulating students' interest in learning. Its value in concretizing geometric knowledge and enhancing students' spatial cognition and logical reasoning abilities has been confirmed by domestic and international research. However, there are still significant bottlenecks in current practice: the uneven distribution of resources leads to a considerable gap in the application popularization rate between urban and rural junior high schools; the insufficient compatibility between game design and the essential nature of geometric knowledge points makes it prone to being a mere formality; the differentiation of student participation and the issue of order increase the difficulty of classroom management; and teachers' lack of gamified teaching literacy and technical application ability restricts the implementation effect of teaching.

In response to the above problems, the optimization countermeasures proposed in this study are highly targeted: the precise matching design of "knowledge points - games" can ensure the implementation of teaching goals, the hierarchical division of labor classroom organization model can take into account student differences and enhance participation, and the systematic teacher training system can effectively improve teachers' practical operation ability. The three parties have jointly constructed a gamified teaching system that is adapted to the geometry discipline and students' learning conditions, providing a practical reference plan for the reform of junior high school geometry teaching and laying a foundation for the subsequent in-depth research on the long-term effects of gamified teaching.

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