Research on the Cultivation of Creative Thinking in Middle School Physics Teaching

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Abstract. The cultivation of creative thinking is of great significance in middle school education. Based on the history of pedagogy, this paper reviews the research process of students' creative thinking at home and abroad, integrates their existing definitions, and analyzes the significance of cultivation. Based on the former research on physics teaching methods in middle school, this paper summarizes the methods of cultivating creative thinking in middle school physics teaching, the obstacles it faces, and the solutions to the challenges. Also, it provides references for developing creative thinking in middle school physics teaching in the future.

Keywords: middle school physics, creative thinking, teaching, thinking cultivation CLC number G632.0 Document code A

1. Introduction

Creative thinking is a necessary thinking quality for innovative talents with creative consciousness in today's information-based society, so it is very crucial to cultivate students' creative thinking in current teaching. We should integrate the cultivation of creative thinking into the physics teaching process, which enormously boosts students' learning of physics and the construction of physical thinking systems. Scholars at home and abroad have also conducted long-term research on cultivating creative thinking.

Foreign studies have shown type and age differences in teenagers' creative thinking development. Dr. Kalmykova of the former Soviet Union conducted experiments on the creative thinking of students in primary and secondary school, and her research shows that there are different types of creative thinking, including balance type, practitioner type, and theorist type. Students of different ages have other characteristics of creative thinking. Education can achieve better results only by starting from the features and laws of the development of creative thinking of young people. British psychologist G.Wallas[1] put forward the "four stages of creative thought": preparation, incubation, understanding, and verification. According to Osborn's Brain storming, Gordon's histography, Guilford's structure-of-intellect theory, and Marceau's "Needs and perception training strategy", Parnes[2] proposed the CPS model, which is the "five-stage model". On implementing creative education, the former Soviet educator Sukhomlinsky put forward: 1. Take a thinking class. 2. Engage in creative labor. 3. Provide a varied spiritual life. 4. Discover and cultivate creative teachers.

Domestic scholars have also studied the cultivation of creative thinking. Chang Wei et al. [3] started to learn creative thinking from psychology. They studied the methods of cultivating students' creative thinking according to their psychological characteristics to achieve individualized teaching and explored new ways of cultivating creative thinking. Cao Baolong et al.[4] advocated that teachers should break away from the traditional teaching mode and establish a new thinking training system, including divergent thinking, transfer training, reverse training, and recombination training. Since solid curiosity and an intense thirst for knowledge are the internal driving forces to promote people's creative thinking, and they are also the premise and key to creativity training, teachers can use experiments and other means to stimulate students' interest in learning[3]. Domestic researchers not only start from the students' perspective but also study the students' learning environment. After comparing the education and growth environment of domestic and international students, domestic researcher Lu Dinglong[5] proposed that experimental teaching should be good at cultivating students' creative thinking, deepen students' understanding of physics concepts and knowledge, and provide

students with a more inclusive and relaxed environment. At home and abroad, creative thinking and its cultivation have been studied for a long time, and many ways of cultivating creative thinking have been put forward, which have important guiding significance for cultivating creative thinking. This paper summarizes and discusses the research results of innovative thinking training in high school physics teaching from definition, teaching importance, problems, and teaching countermeasures.

2. Definition of creative thinking

Creative thinking is a kind of compound thinking which can be defined differently from different aspects. It can be restricted from its components and according to the process, state, and result of thinking activities. Chang Wei et al.[3] believe that creative thinking is an open way in which people break the conventional understanding and seek ways to solve problems from various aspects according to different information of research objects. It is the foundation and core of all creative activities and the advanced form of human thinking. Similar to this definition, Zhang Liyong et al.[6] put forward that innovative thinking is the most advanced form in which people solve problems using the concepts, principles, laws, and formulas they have learned. The ultimate goal of this form is to explain the nature and internal relations of objective things and produce novel and creative thinking results. The core of creativity is divergent thinking and convergent thinking. As for convergent thinking and divergent thinking, Yue Xiaodong et al.[7] defined it as Convergent thinking, which is the product, understanding, and application of existing information. Divergent thinking is the imagination and assumption of unknown details, which is the formation of new information. Convergent and divergent thinking complement each other and organically combine to form the basis of innovative thinking. On a larger scale, all that is "new" can be defined as creative thinking and its associated activities. It is an activity of creative thinking to discover new things, suggest new laws, establish new theories, propose new hypotheses, create new methods, invent new technologies, and solve new problems[8]. Based on various intellectual and non-intellectual factors, it uses existing knowledge to process thinking, such as imagination, reasoning, analysis, and synthesis, to obtain new knowledge it has not yet set foot in[9].

Zhang Lihua[10] proposed that the definition of creative thinking is mainly reflected in three aspects: process, state, and result. It is a mental activity based on various abilities characterized by comprehensiveness, exploration, and understanding. It is all kinds of thinking conditions of people under the effect of the best psychological composition and psychological synergy, such as intuition, inspiration, and creative imagination; Thinking produces novel results. In the teaching process, creative thinking leads students to seek the essence of things through the surface of things and dig out the real connotation of things[11].

Combining the understanding and cognition of these scholars on creative thinking, it can be concluded that innovative thinking is mainly composed of convergent and divergent thinking. It is a way of thinking that creatively raises and solves problems through the knowledge, methods, and experience that have been mastered and acquired and through repeated thinking. It is an organic combination of seeking common ground and seeking differences. It is a thinking activity with pioneering significance. In the process of physics teaching in middle school, creative thinking is the thinking ability of students to grasp the essence of physics problems and solve physics problems creatively.

3. The significance of cultivating creative thinking

In the current era, the lever to promote the development of science and technology needs to take scientific and technological innovation as the fulcrum. From the macro background, the national innovation force fosters national scientific and technical innovation development. The innovation ability of the nation and its growth depends on the cultivation and creation of high-quality talents[7]. In the high-tech information society, creative thinking is necessary for creative skills with pioneering

and innovative consciousness[9]. Therefore, from a micro perspective, as the main force leading the development of science and technology in the future, middle school student's mastery of creative thinking is directly related to the strength of their innovative ability in various fields in the future, so the cultivation of students' innovative ability should be included in the critical training objectives of quality education. As an essential part of the knowledge system of middle school, physics is a subject that studies the general laws of material motion and the basic structure of matter, and its fundamental theories have penetrated all fields of natural science. Students' high-level creative thinking will significantly benefit the future development of natural science and social economy[12]. Training students' creative thinking helps them grasp the core of physics thinking quickly and accurately, solve physics problems creatively, and build a complete physical science thinking system, thus laying a good foundation for physics learning.

4. Cultivation of creative thinking (current problems and teaching methods)

In middle school physics teaching, teachers need to establish new concepts of curriculum reform, break traditional teaching concepts, take students as the main body in class, give full play to students' subjective initiative, and allow students to think independently[13]. At the same time, various methods are used to cultivate students' creative thinking. As shown in Figure 1, it is mainly divided into three aspects:(1) Cultivation methods of students' cognitive and thinking ability; (2)Methods of teacher teaching; (3)Cultivation methods of students' autonomous learning ability.

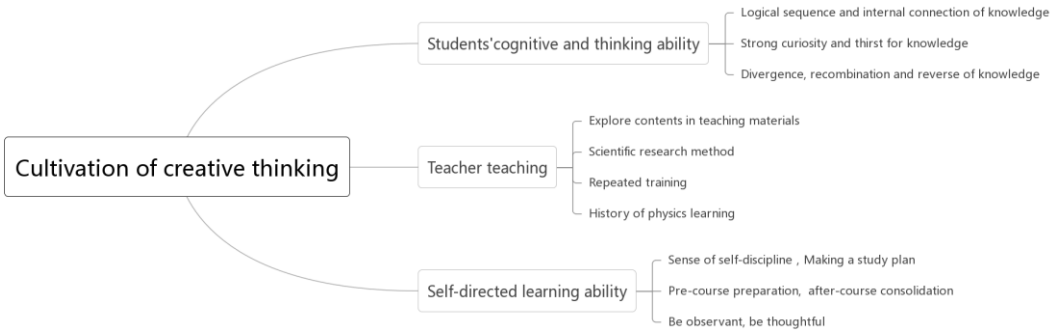

Figure 1 Cultivation of creative thinking

From the perspective of students' cognition, the famous cognitive psychologist Ausubel[5] proposed that cognitive structure is the knowledge structure in students' minds. And the higher the degree of consolidation of the original knowledge is, the more conducive it is to promote another kind of new learning. Lu Dinglong[5] proposed that, in teaching, teachers should carefully design the logical order of the structure of classroom content, organize the transitional language between knowledge points, reveal the internal relations between knowledge points, and study the obstacles and misunderstandings that students may encounter in the thinking process of comprehending knowledge. At the end of each chapter, teachers outline the knowledge structure, which helps students construct the subject knowledge system and lay a good foundation for developing creative thinking. Curiosity and thirst for knowledge also play an essential role in promoting thinking. Curiosity is the tendency of people to pay attention to new things, and thirst for knowledge is a psychological state of people who are eager to acquire new knowledge. Intense curiosity and a strong thirst for learning are the internal driving forces to promote people's creative thinking, and taking the initiative to carry out creative thinking is the premise and vital in cultivating creativity[3]. Combining the characteristics of creative thinking with physics teaching[4], several thinking teaching methods, as shown in Figure 2, can be obtained.

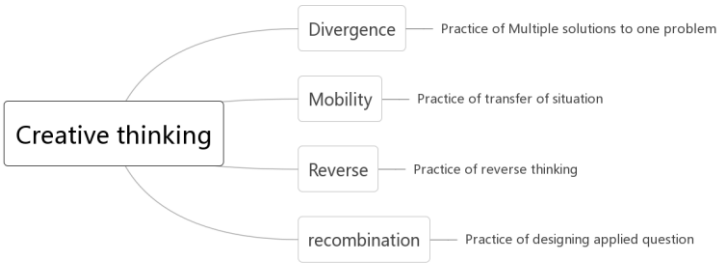

Figure 2 Teaching methods

The divergence of creative thinking can be trained with multiple solutions to one problem. The transfer of concepts can qualify mobility. Reverse can be taught by reverse review, which plays a vital role in solving more complex problems and may open up different solutions to problems. Recombination training can be achieved by rearranging word problems[4]. In addition, questions can motivate students' thinking. Sun Jianjun[14] believes that students can actively explore and think only when they have questions. For example, experiments can be reasonably applied to solve the problem in the teaching process. In teaching atmospheric pressure, it can be demonstrated that the closed end of a glass tube with a slightly smaller diameter is slowly inserted into a glass tube with 3/4 water. At the same time, after reversing the two tubes slightly faster by 180°, the small tube will move to the top of the big tube. Water will flow out of the big tube[3]. At this time, students had questions and curiosity about the upward movement of tubules under the pressure of gravity and water, which triggered their thinking about the cause of this phenomenon: the effect of atmospheric pressure on tubes.

Teachers' teaching method is a critical factor in promoting student creative thinking development. Chang Wei[3] proposed that exploring creative materials in teaching materials and designing creative teaching activities are the basis for cultivating students' creative quality. Reading textbooks is a significant channel for students to acquire knowledge. Hence, the content of textbooks is worthy of teachers' exploration, and how to use innovative training methods to teach the content of textbooks is worthy of teachers' thinking and practice. First of all, the textbook includes a relatively complete physical knowledge system, which is helpful for students to construct the knowledge system and carry on the comprehensive application of various concepts. Secondly, the textbook contains abundant scientific research methods, including experiments, observation, analysis, analogy, induction, etc.

These scientific methods play an essential role in scientific understanding and greatly benefit students' learning process. For example, analogy can help students understand new knowledge, simplify memory, inspire thinking, provide clues, and infer by analogy. An ideal model can help highlight the essential characteristics of things[5]. The association method can broaden horizons and enlighten thinking by linking knowledge vertically and horizontally and making associations[15]. However, creative thinking depends not only on clever teaching methods but also on repeated training based on those methods. Ge Dianzhong[15] pointed out that the fruits of creative thinking can only be achieved through the repeated process from divergent thinking to convergent thinking and then from convergent thinking to divergent thinking. In physics teaching, "typical examples" carry out exercises of "one problem with multiple solutions," "one problem with multiple changes," and "one problem with multiple uses" to guide and inspire students to analyze knowledge structure and correctly understand what they have learned, to carry out divergent thinking training and make their thinking have broad, flexible and creative qualities. In addition, teaching should not be rushed but gradually cultivated because the fundamental purpose of education is to make creativity internalized in students' thinking so that students naturally have the quality of creative thinking. It is one of the teaching methods for teachers to link the teaching content with the practical problems of life in a planned way so that the cultivation of innovation ability is closely combined with physical knowledge and valuable life[15]. However, students should not only learn theoretical concepts but also master physics-related knowledge, including the history of physics. The teacher uses the history of physics to illustrate how

new knowledge arises when an old acquaintance encounters difficulties and contemporary contradictions. Teachers consciously guide students to follow the footprints of this part of the history of physics, combine the introduction, expansion, deepening, and application of the subject, and refine the scientific thought method and the will quality of scientists[5] so that students can understand that even outstanding inventors and scientists are not born with innovative thinking and ability. It is acquired through continuous learning, training, and practice[12]. This can not only promote students' cognition of the history of physics but also implement the ideological and political requirements of the course.

Students' independent learning is another crucial factor that affects the learning results. The new curriculum reform of physics encourages students to stand in the prominent position of teaching, and independent learning becomes an inevitable requirement. In the tide of information-based technology today, independent learning is needed for individual development and is the key to improving students' learning efficiency[16]. Through investigation, Chen Pin[17] concluded that excellent academic performance is linked with a high level of independent learning ability. Students with outstanding academic performance often have a strong sense of self-discipline, and they also use scientific methods to exercise and consolidate what they have learned outside the classroom and make learning plans suitable for themselves. In the process of actual learning, there are many ways to promote the development of creative thinking through independent learning. In all things, success lies in previous preparations, and there will be failure without prior practices. To clear the thoughts and improve the efficiency of the class, we should preview the new knowledge before the course, find out the breaking point of thinking, and take a class with questions[18]. Homework after class is essential for students to consolidate what they have learned and improve their core qualities. It is also conducive to the breakthrough of students' physical thinking[18]. When solving problems, different methods can be used to mobilize thinking. We can also use varied exercises to get out of the box and try to understand physics in various ways to improve thinking logic[19]. However, it is far from enough to consolidate knowledge and open up thinking only by solving problems. The reflection and summary of the learned knowledge is an indispensable link to independent learning. Physics learning requires students to memorize more concepts, phenomena, and experimental conclusions. Summarizing new knowledge and problem-solving methods after class can make students' knowledge more systematic and logical, which is conducive to rapid extraction in application[16]. However, learning is not limited to the classroom but also can be exercised in life. In real life, we should be good at observing and thinking diligently, combining the learned physical theory with practice, and applying what we have learned in real life. We should think more, use questions to improve thinking activity and use biological knowledge in practice to stimulate creative thinking[19]. Chen Pin[17] concluded that the cultivation and improvement of independent learning ability can enable students to have a scientific understanding of their learning ability, adjust their learning state from different aspects, and constantly optimize and innovate the learning content and rhythm to improve learning efficiency.

5. Problems and solutions in the process of cultivating creative thinking (the problem part can be used as a summary of the new edition)

Cultivating students' creative thinking is an integral part of physics teaching in middle school. However, developing creative thinking is complex, and there are many problems in the teaching process, including teachers' improper teaching methods and students' issues. The main problems in teachers' teaching are as follows: First, teachers pay too much attention to the conclusion in the teaching process, ignore the explanation of the physical thought process and the application process, and do not pay attention to the connection between the physical concept and the application process. Many teachers pay more attention to the conclusion in teaching and do not strictly deduce and explain the physical thought process, which will cause the students' understanding of the biological concept not to be deep enough. Today's physics teaching focuses on theoretical knowledge and discussion under idealized conditions. It lacks awareness of the connection between ideal models and practical

applications, with little introduction to physics application knowledge, resulting in a disconnect between theory and practice[20]. The second is the lack of innovative experimental teaching. The current physics experiment teaching relies on traditional teaching methods, and the model is relatively fixed[21]. Usually, with the physics teacher guiding the experiment steps, students complete the experiment step by step and have less space for independent thinking and exploration[17]. At the same time, the development of science and technology has increased the degree of automation of teaching instruments, resulting in simple operation steps and unclear physical structure of instruments when students do experiments, which limits the formation of students' innovative thinking[21]. For example, in the "voltammetry to measure resistance" experiment, students only understood that internal and external connection methods would produce errors. Still, they did not continue to think about how to minimize the mistakes and seek the optimal solution. Third, there is a severe shortage of courses to foster creative thinking. At present, the classroom teaching purpose of our country is more inclined to let students firmly grasp the knowledge of the textbook rather than guide students on how to use creative thinking to think about problems. The development of students' thinking is a shortcoming of Chinese education. The lack of training in students' creative thinking in Chinese education leads to the lack of awareness of in-depth exploration and challenging authority, and students tend to develop in the direction of "high memory and low creativity" in the learning process[7]. When Qian Yingyi[22] taught at an American university, she found that compared with international students, Chinese students usually had no advantage when they reached the frontier of knowledge and needed to explore new knowledge by themselves. Fourth, the stifling of students' creative thinking exists under exam-oriented education. Today's education focuses too much on academic performance while suppressing the play of creative talent, which is not beneficial to the development of creative thinking from the perspective of individuals. From the standpoint of society, this development model is unsuitable for the future community with high flexibility and changes[7]. Teachers often reject questions students raise because they break the original knowledge system, which virtually suppresses curiosity and imagination.

The longer the education period is, the more thoroughly the germination of creative thinking will be strangled[22]. Fifth, utilitarianism prevails in teaching. Qian Yingyi[22] proposed that the current impatience in teaching for quick success and short-term results has seriously affected the cultivation of students' creative thinking. Teachers tend to focus on improving students' problem-solving ability and test scores while ignoring that cultivating creative thinking is not overnight and the increase in creativity results from long-term subtle effects. Sixth, people confuse the relationship between intelligence and creativity and equate high intelligence with high creativity, which leads students to the direction of "intelligence is above everything, and results determine the universe." Also, "valuing intelligence and undervaluing creativity" is also quite common in educational research. For example, there are more studies on the intelligence of supernormal children but fewer studies on the unique abilities of supernormal children, such as music, painting, and sports[7]. Gilford summed up the relationship between intelligence and creativity from the perspective of psychology:

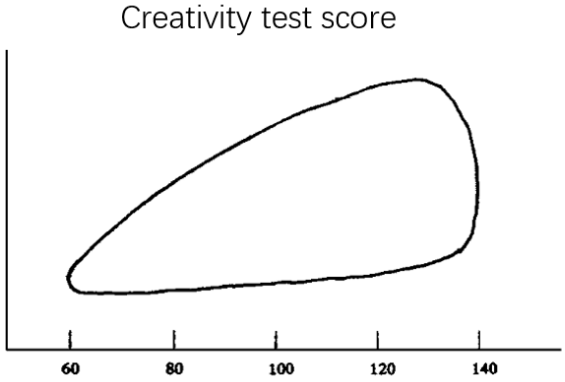

Figure 3 Creativity test score

As can be seen from the figure, there is a trend of positive correlation between creativity and intelligence. The higher the IQ is, the lower the correlation with creativity is. The higher the intelligence is, the higher the creativity may not be. High intelligence is a favorable condition for increased creativity but not a prerequisite, and there is no absolute relationship between creativity and intelligence[7].

In cultivating creative thinking, students' factors mainly include: first, they fear the outside world's doubts and negations and dare not think out of the conventional way to look at problems. Teachers and even parents often consider problems with fixed thinking, and their negation may stifle students' new ideas in the cradle. Over time, students will be trapped in the same thinking set and dare not jump out of the thinking set to look at and solve problems. Zhang Lihua et al.[10] believe that when an individual's psychological security or freedom is satisfied, the individual can freely express his thoughts, independently shape his personality, and show high creativity. Second, the training of students' divergent thinking is not valued. Multiple solutions to one problem are an essential way to train divergent thinking. The cultivation of convergent and divergent thinking among today's students is unbalanced. Yue Xiaodong[7] put forward that without divergent thinking, there would be no imagination, foundation, and motivation for innovation and change. In today's exam-oriented education, the so-called "standard answer" will also cause students to pay no attention to multiple solutions to one question. Third, they cannot summarize what I have learned. Compared with other subjects, physics is more complicated and has a broader knowledge range, making it easy for students to feel bored in learning. Moreover, students may confuse knowledge before and after learning new knowledge if they do not summarize it in time[23]. To solve these problems, the following solutions can be summarized: (1) Pay attention to the derivation of process and the application of knowledge, and give students have a deeper understanding of knowledge. (2) Consciously guide students to train divergent thinking and innovative thinking. (3) Abandon utilitarian teaching and promote the liberalization of the classroom atmosphere.

The learning process of physics concepts and applying physics knowledge in life. Yang Zhenning once put forward: "Phenomenon is the root of physics." Therefore, in physics teaching, the introduction of concepts should depend on the phenomena in reality or experiments[24], which connects physical ideas with the facts of life. Physical concepts are derived from observation or derivation, which determines that teaching physical concepts should not only focus on the conclusion but ignore the process's deduction and interpretation. Xing Hongjun et al.[24] believe that the teaching of physical concepts and laws should not only be satisfied with drawing definitions or expressions but also pay attention to the interpretation of the nature of biological concepts and regulations, including connotation, extension, conditions of use, and the physical thoughts and ideas behind them, to enable students to understand the nature of physical concepts and laws truly. And the learning of physical concepts can be firmly grasped by more than mere derivation. The research of physics educational psychology shows that only through applying physics concepts and laws can students understand more profoundly and hold more firmly[24]. Physics comes from life, so physics teaching and applying physics knowledge in life are also conducive to students' learning of physics knowledge. As mentioned above, today's physics teaching widely adopts the tactics of practices so that students ignore the hidden nature of physics in life, which is no different from the problem of students' physics learning. For this kind of teaching dilemma, Ma Xiaozhuang et al.[23] put forward that it is a suitable teaching method to carry out physics learning in daily practice and connect with everyday reality in exercise design.

The training of divergent and innovative thinking can mainly start from theoretical and experimental teaching innovation. In academic teaching, teachers should consciously cultivate students' divergent thinking abilities, guide students to use the comparative method and association method to find the connection between physics concepts and laws, the connection between physics knowledge and daily life, and the application of physics knowledge in the field of technology, which can help students overcome the rigid understanding of physics knowledge and improve the fluency and flexibility of physical thinking[13]. There are also two innovative teaching methods: the splitting

method and the categorization method. The splitting way can decompose more complex problems into several simple problems and then break through them one by one, which is conducive for students to make corresponding associations. The classification method can classify research objects with different characteristics to avoid confusion of physical knowledge[25]. As for experimental teaching physics as an experimental science, Lu Dinglong[5] proposed that experimental observation is not only the basis of learning physics but also the source of developing creative thinking. Teaching in experiments can improve students' observation ability and acuity of thinking. It can engage students in law generation and deepen their understanding of physical concepts and laws. Various experimental methods, such as open experiments, designed experiments, and research experiments, can open up students' thinking, make students break through the thinking set, increase students' interest in physics learning, and promote the transformation of students' cognitive structure[13]. It can be seen that the innovation of physics experiment teaching methods is vital to promote the progress of physics teaching. Chen Pin[17] believes that physics teachers can prepare relevant experimental equipment and set relevant experimental problems for students based on their actual situation and experimental purpose so that students can independently think, design, and practice experiments according to the guidance of experimental issues, and observe whether the expected results have been achieved. If there are errors or significant errors in the experimental results, the reverse analysis of the design of the experiment is unreasonable and then constantly adjusted and optimized. For example, in the experiment of "measuring resistance in voltammeter," students were guided to maximize the elimination of errors, and students naturally developed the idea of measuring resistance by bridge method after thinking, discussing, and teachers' instructions[5]. In a word, the innovation of physics teachers' teaching methods is of great help to cultivate students' creative thinking. In training, physics teachers should explore various training methods in multiple aspects and continue to train students' creative thinking.

To abandon utilitarian teaching and promote the liberalization of the classroom atmosphere. Under exam-oriented education and general short-term utilitarianism, students want to achieve immediate results in their scores with the "tactics of practicing questions" as the standard. However, this is not the case, and creative and long-term results are often tricky and difficult to quantify[22]. In the background of helpful teaching, teachers will inevitably suppress students' thinking, which will also suppress students' innovative thinking, making them uncreative and trapped by fixed knowledge. Psychological research shows that to transform potential creativity into actual creativity. There must be an environment and atmosphere to stimulate potential and form creativity[3]. Therefore, in the classroom, teachers should strive to create a relaxed, harmonious, and mutually respectful classroom atmosphere, respect students' personality development, encourage students to express their own opinions and allow students to have different views[13]. Absurd ideas not in line with reality should not be downplayed, and their bold, innovative spirit and thinking ability should be fully affirmed[8]. In addition, in the teaching process, we must put ourselves in a more equal position to explore with students. From any student's point of view, it is necessary to think carefully, affirm rationality, seek the coincidence point with their existing knowledge, and then supplement or expand it to help students improve their unreasonable aspects. In short, fully respecting students' prominent positions and abolishing teachers' absolute authority are the prerequisites for implementing creative teaching and cultivating students' creative thinking. Students can produce novel and valuable results only by establishing a democratic, harmonious, and pleasant classroom teaching environment and encouraging students to be innovative and fully display their individuality[8].

6. Conclusion

By combing and summarizing the history of pedagogy, it is found that the cultivation methods of students' creative thinking in middle school physics teaching are worthy of further exploration, and the cultivation methods obtained by the current research are also effective. Creative thinking is a creative way of thinking and a pioneering thinking activity, which is significant for middle school

students to learn physics knowledge and improve their physical literacy. Teachers can improve students' creative thinking ability by giving full play to students' subjective initiative and using multi-angle and multi-aspect methods in teaching. Under the background of the new curriculum reform, teachers should change teaching ideas, innovate teaching methods, and gradually overcome the related problems brought by traditional teaching methods to promote the development of students' creative thinking.

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