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Strategies for Cultivating Innovative Thinking in High School Chemistry

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Abstract: *The study of high school is a crucial period for cultivating students' independent and innovative thinking abilities. The study of chemistry courses is also an important discipline for training students' hands-on and brain skills, and developing their thinking abilities. The traditional education method places too much emphasis on imparting knowledge while neglecting the subjective status of students themselves, which inevitably leads to various loopholes. Therefore, it is particularly important to adopt innovative teaching methods, stimulate students' interest in learning, and strengthen and attach importance to the cultivation of students' innovative thinking and innovative abilities. This paper analyzes and elaborates on the cultivation of innovative thinking and ability in high school chemistry education, and proposes strategies and methods for cultivating students' innovative thinking and ability.*

Keywords: *high school chemistry, innovative thinking, teaching*

1. Introduction

Innovative thinking is a high-level way of thinking and activity in which humans, based on their existing cognitive abilities, generate cognition, understanding, association, break through conventional thinking patterns, and think deeply from multiple perspectives in the process of production and practice, in order to propose new insights or unique problem-solving solutions to things, improve or create advanced thinking methods and new achievements that are useful to society. The high school chemistry curriculum standards require the subject literacy of "innovative understanding"[1]. Understanding is a cognitive acceptance activity, and thinking is a comprehensive psychological activity of cognition, thinking, and problem-solving. Whether it is innovative understanding or innovative thinking, innovation is the key, and understanding is the prerequisite for innovation.

Chemistry is a discipline based on experiments, and important chemical experiments and understanding of chemical historical facts originate from practice. Chemistry is also an interesting subject that can always bring unexpected surprises. The discipline of chemistry has strong theoretical knowledge and practical significance, which needs to be understood and applied. At the same time, relying solely on theoretical knowledge learning is not enough, but also needs to be combined with practical operations, that is, chemical experiments and experiments [2]. In order to provide students with a more intuitive understanding, they are required to operate by themselves. We often say that it's better to pass through a thousand times with your eyes than with your hands. Teachers can lead students into the chemistry laboratory for classes, and when faced with various experimental instruments, students' attention will be involuntarily attracted. As long as it is a chemical experiment involved in the textbook, teachers can lead students to carry out practical operations. It can be demonstrated by the teacher first, and then led by the students to operate it together. The first chapter of the new teacher's version of high school chemistry is about "Learning Chemistry from Experiments"[3]. Therefore, learning chemistry and conducting experiments are essential and important contents. Conducting chemical experiments not only stimulates students' interest in learning chemistry courses, but also deepens their memory and consolidation of chemical knowledge, as well as exercises their practical operation abilities.

Chemistry originates from and serves daily life, and is effectively applied in daily life. Teachers can fully connect chemical knowledge with practical life while teaching, allowing students to have a more intuitive experience. For example, the black substance in black and white photos is metallic silver; The concentration of medical disinfectant alcohol is 75% (70% also exists); The naphthalene hygiene ball becomes smaller when placed in the wardrobe, because naphthalene slowly sublimates at room

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temperature; The iron wire purchased in a hardware store is coated with a "anti-corrosion" metal, which is zinc; An all steel watch refers to a watch whose case and back cover are all made of stainless steel, which is shiny and does not rust, due to the addition of chromium and nickel during the steelmaking process; Mr. Hou, a world-renowned alkali making expert in China, invented the Hou's alkali making method in 1942. The chemical name of this alkali is sodium carbonate; After being bitten by mosquitoes, the skin becomes itchy or swollen. The simple treatment is to wipe with dilute ammonia or sodium bicarbonate solution. These are common chemical knowledge in daily life, and teachers should intersperse them in their lectures to help students understand. On the one hand, they should arouse students' curiosity, and on the other hand, encourage them to discover these small knowledge in life to help them learn chemistry courses. The combination of theoretical knowledge and practical life is one of the effective methods to construct an efficient high school chemistry classroom in the context of the new curriculum. Therefore, chemistry is a highly theoretical and practical scientific course. In the process of high school chemistry teaching, teachers should discover and protect students' innovative thinking, and consciously cultivate students' innovative thinking.

2. Current situation and existing problems in high school chemistry teaching

With the introduction of various systems in the new curriculum reform, many teachers are seeking new teaching methods, but there are still many problems in the actual teaching process.

2.1 Fixation of teaching mode

Although high school chemistry has a lower proportion in the college entrance examination than Chinese, mathematics, and foreign languages, it is also a very important subject. Some teachers only consider the impact of the pressure of entering the college entrance examination and do not pay attention to students' own interests. Instead, they simply explain and memorize theoretical knowledge of chemistry in the chemistry curriculum, resulting in students only memorizing knowledge rather than truly understanding the deep meaning it contains [4].

2.2 In the teaching process, theoretical knowledge accounts for a relatively heavy proportion

Although there are experimental courses in high school chemistry, some teachers skip the experimental courses because they do not pay attention to the experiments in the course, or directly demonstrate the experiments to students in class, or have a classmate demonstrate the experiments. This will affect students' hands-on and brain skills, and overlook the experimental nature of chemistry itself. Therefore, students only have overlapping theoretical knowledge in their memory, without a deep understanding.

2.3 The teaching atmosphere is too tense

Theoretical things themselves are slightly difficult to understand. If the classroom atmosphere is too calm, students will be more depressed, especially those with poor grades. Even if they don't understand, it will hinder their face and they are unwilling to ask questions, which undoubtedly dampens their learning enthusiasm.

2.4 Insufficient teaching facilities

Some high school experimental facilities are not complete enough, such as the most commonly used heaters, meters, separators, collectors, dryers, etc. The lack of meters may cause deviations in experimental results, and some drugs may be replaced by similar drugs in schools, which inevitably affects the accuracy of the experiment and causes errors.

3. Construction strategies for innovative thinking in high school chemistry

3.1 Craft problem scenarios, break away from fixed thinking patterns, and guide students to analyze problems from multiple perspectives and perspectives

Situational teaching is a commonly used teaching method, and discovering chemical problems in the context is the source of updating thinking activities for learners. Situational teaching should not be

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limited to superficial situational cognition. In teaching, teachers should adhere to the characteristics of the chemistry discipline of "change oriented and diverse transformation pathways", and appropriately set up scenarios that students are familiar with and closely related to chemistry and life according to the teaching objectives, in order to meet the needs of learners' cognition, understanding, and ability improvement. Based on the learning objectives, teachers should ask questions and cooperate with students in a timely manner, it guide students to conduct in-depth analysis, and cultivate their innovative thinking ability Provide a good platform for implementing chemical discipline literacy.

Case: During the lesson on "Properties of Hydrogen Peroxide", the teacher played a video: A student accidentally sprinkled potassium permanganate on a tile floor with water, and wiping it with a towel could not completely remove the dazzling red stains. Then the teacher showed the family's regular medications such as iodine, hydrogen peroxide, and metoclopramide (mainly composed of aluminum hydroxide), and asked students to find ways to help students remove red stains. Classmate B's analysis: Aluminum hydroxide does not react with potassium permanganate, and iodine wine contains ethanol that has reducing properties. Potassium permanganate can be reduced to colorless divalent manganese ions, so iodine wine is chosen. Classmate C refuted with the reason that although ethanol can reduce potassium permanganate, the rate is slow and requires heating, making it difficult to operate. Ethanol volatilizes in open spaces and is flammable and unsafe. Iodine in iodine liquor itself appears purple brown, forming new brown stains. The teacher fully affirmed the students' approach to using the principle of redox reaction to solve problems, praised the comprehensiveness of student C's consideration of the problem, and guided the students to analyze the negative valence of oxygen element in hydrogen peroxide. Hydrogen peroxide is not only a strong oxidant, but also can lose its electronic performance and its oxidation product is oxygen. Therefore, H_2O_2 can be chosen to use its reducibility to remove the red stain of potassium permanganate. By cleverly setting up real-life scenarios, teachers guide students to break free from their habitual thinking patterns, break free from their fixed thinking patterns, and enable students to analyze and think about problems from multiple dimensions and perspectives, thus finding the best way to solve chemical problems.

3.2 Emphasize "heretical" thinking and establish a column for disciplinary innovation and discovery

In teaching, teachers should be good at discovering students' unconventional thinking. For some minor issues discovered by students, teachers should carefully inquire, communicate with students equally, and openly discuss these issues, allowing all students to participate in thinking, discussion, and exploration [5]. Due to different levels of cognitive experience and ways of thinking, students may raise different questions. Some students' thinking may break away from conventional thinking, or even deviate from teaching objectives, appearing very "heretical". For these issues, as long as they have scientific basis and rational thinking, teachers should actively treat them and guide students to explore towards scientific and rational thinking. Teachers can establish a subject discovery column to preserve unknown problems for students to think and explore.

Case: Answer exam questions. In the preparation of Al_2O_3 by electrolysis, Al is connected to the positive electrode of the DC power supply, a carbon rod is connected to the negative electrode of the DC power supply, and dilute H_2SO_4 is added as the electrolyte solution. This question requires writing the anode reaction equation, and the answer is: $2Al+3H_2O-6e^-=Al_2O_3+6H^+$. After analyzing the answers, the student raised a question: Why does the product Al2O3 in this electrolysis method not react with dilute H_2SO_4 to generate aluminum sulfate? Teacher's explanation: The Al_2O_3 produced in this reaction has properties equivalent to the passivation product of metal aluminum. But students still have doubts. This problem has surpassed the level of high school chemistry knowledge and is not related to the requirements of the topic. However, students are able to discover and propose this problem based on their knowledge, and their awareness of exploring and innovating is obvious, which is commendable.

3.3 Establishing a chemical innovation interest group and strengthening experimental exploration practice

Chemistry is a highly practical and operational course aimed at studying the composition of substances, exploring their properties, and exploring the laws of internal connections. Experiments are a necessary condition for learning chemistry courses. With the mature application of interactive multimedia technology, some time-consuming, polluting, and dangerous experiments have been replaced by video demonstrations. The video demonstration experiment has vivid visuals, clear explanations, and strong observability. Students learn in a relaxed and enjoyable environment, greatly

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improving teaching efficiency. But students have fewer opportunities to conduct hands-on experiments, which means they have fewer opportunities to discover, raise, and innovate their thinking to solve problems.

Case: In exploring the reaction products of $BaSO_3$ and dilute HNO_3, based on the redox reaction theory in textbooks, HNO_3 with strong oxidizing properties can oxidize $BaSO_3$ with reducing properties to form a white insoluble substance $BaSO_4$. During the experiment, the experimental team members first prepared $BaSO_3$ precipitates using Na_2SO_3 and $BaCl_2$, and then added HNO_3 to observe the phenomenon. The results showed that the white precipitate $BaSO_3$ dissolved, generating a colorless and pungent gas that can cause the color of magenta solution to fade and recover to red after heating, indicating the presence of sulfur dioxide in the product. The experimental results did not predict the white precipitate of $BaSO_4$ and the formation of nitric oxide gas by students using the redox theory. The students were very surprised and questioned the textbook knowledge. The teacher first asked the students to carefully examine the experimental operation and guide them to carefully analyze the establishment of dissolution equilibrium of $BaSO_3$ and the diversity of HNO_3 properties. The student analyzed the reason for the abnormality in this experiment: during the experiment, due to not adding HNO_3 dropwise as required, but pouring HNO_3 in, the surface H^+concentration of $BaSO_3$ precipitate was relatively high, and HNO_3 mainly reflected acidity, that is, H^+preferentially reacted with SO_3^{2-} to generate SO_2, which was inconsistent with the phenomenon in the textbook experiment. In this experimental exploration and practical operation activity, students deeply realized the complexity and diversity of material properties. Improper operation, different control of reagent dosage and reaction conditions in the experiment can all lead to abnormal side reactions. Through this experiment, students have understood the concept of "change" in chemistry and improved their literacy in the field. In chemistry teaching, we should attach importance to open experiments, create and design experiments for students, allow them to personally carry out practical operations, and enable them to discover, raise, explore, and solve problems through innovative thinking.

3.4 Establish a reward mechanism to encourage students to improve traditional experiments

The theory and application of chemistry cannot be separated from experiments. The verification of known conclusions requires experiments, while the exploration of unknown things still requires experiments. For middle school students, although experimental results are important, identifying problems during experimental operations and processes is even more important. In traditional experimental teaching, teachers first narrate the experiment, learners take notes, then complete the experimental operations step by step, and then fill out the experimental report. Some learners even do not conduct experimental verification and simply copy the experimental report based on what the teacher has said. In traditional experiments, students are only the executors of the experiment who complete the teacher's commands, with dull thinking and a lack of innovation. Schools should establish a sound reward system, encourage students to carefully identify problems, break through the constraints of traditional experiments, encourage students to improve and innovate on outdated and unreasonable experiments, and independently design experiments.

Case: In the comparative experiment of exploring the reducibility and bleachability of sulfur dioxide, the content of the textbook experiment is to use an appropriate amount of sodium sulfite solid and concentrated sulfuric acid to heat and react to prepare sulfur dioxide in a circular bottom flask, and then pass the sulfur dioxide gas into a magenta solution and a purple acidic potassium permanganate solution for comparison. This experiment involves the preparation of sulfur dioxide, which involves a large number of pharmaceutical reagents and complex equipment. After thinking about it, Classmate A changed the experiment to: prepare two 10ml small bottles containing a small amount of magenta and iodine water, light a match (containing sulfur), quickly insert the two bottles, repeat multiple times, and shake the two bottles for comparison. This way, the experimental reagents have easy access to raw materials, fewer materials, less pollution, simple operation, and obvious phenomena. The second student changed the preparation of sulfur dioxide to using spiral copper wires to pass through rubber plugs and react with concentrated sulfuric acid under heating conditions. Changing the straight copper wire to spiral shape can increase the contact area between the copper wire and the acid reaction, and the reaction can be controlled by pulling the copper wire to proceed or stop. Compared with the traditional experiment of adding copper strips to concentrated sulfuric acid, the improved experiment has a faster reaction rate and stronger controllability, and the innovative thinking achievements of students have been specifically reflected. Under the incentive system, students gain a sense of achievement in innovative experiments, have motivation and passion for learning, and their academic literacy can also be improved.

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3.5 Guiding learners to think in multiple dimensions and flexibly solve chemical problems

In chemistry classroom teaching, teachers can guide learners to think multi-dimensionally and solve chemistry problems through teaching methods such as displaying pictures, physical objects, examples, analogies and associations, and inspiration.

Case: In the conservation method calculation, known information: adding ymolZn to a solution with an unknown concentration of xmolHNO_3, the metal happens to completely dissolve. Calculate the number of moles of HNO involved in the reduction reaction? Under the traditional solution, students first need to consider various possibilities of nitric acid reduction products being oxides of nitrogen, such as NO and NO_2, which greatly interfere with the calculation. The reverse thinking method can be adopted, which considers the conversion of HNO_3 that has not been reduced to zinc nitrate. Due to the perfect reaction between metal Zn and HNO_3, based on the conservation of Zn atoms, the amount of zinc nitrate can be determined as ymol. According to the chemical formula composition of zinc nitrate, it can be seen that there are 2ymol nitrate ions that do not participate in the reduction reaction, so the amount of reduced HNO_3 material is x-2ymol.

3.6 Utilizing the advantages of chemistry discipline, organizing students to participate in scientific and technological innovation competitions, and comprehensively improving their thinking and innovation abilities

The ability to innovate requires opportunities for expression and a platform for demonstration. The science and technology innovation competitions organized by various levels of science and technology departments in China provide opportunities and a broad platform for students' innovation. Teachers should encourage students to take advantage of the advantages of the chemistry discipline, actively participate in scientific and technological innovation activities, apply what they have learned, and enhance their innovative thinking abilities.

Case study: In recent years, a large number of innovative achievements have emerged in the scientific and technological innovation activities of middle school students, including the improvement of experimental projects and the production of new substances, fully demonstrating that middle school students have unique advantages in innovation. The experiment designed by a certain student to roughly pretreat a large amount of meal oil solid-liquid mixture using compact gauze instead of filter paper, then separate it through vacuum filtration, and finally use the properties of oil that are insoluble in water and have different densities for centrifugal separation to obtain a relatively pure liquid oil has achieved success, receiving rewards from the science and technology department and praise from society.

4. Discussion

Chemical innovative thinking ability refers to the individual psychological characteristics formed during the process of learning chemical knowledge, using chemical thinking methods to think and solve chemical problems [6]. Since the founding of the People's Republic of China, the cultivation of innovative thinking ability in chemistry has always been an important goal of Chinese middle school chemistry curriculum. With the advent of the knowledge economy era, society has put forward higher requirements for individual thinking abilities, which inevitably puts forward different learning goals for chemical thinking abilities in the basic education stage. Therefore, studying the related issues of chemical thinking ability is an eternal topic in the field of chemical education research. In the current context of focusing on students' core disciplinary literacy, the cultivation of chemical innovative thinking ability has a unique function, as it is the foundation and central link for developing students' core disciplinary literacy. Therefore, in the new educational context, studying the related issues of chemical innovative thinking ability has new significance and value.

5. Conclusion

In summary, high school chemistry is a very important and interesting subject, and the cultivation of students' innovative thinking and ability cannot be separated from the teaching guidance of teachers. Only by constantly seeking and innovating teaching methods, changing teaching modes, combining theory with practice, adjusting the classroom atmosphere, stimulating students' innovative thinking, adopting multimedia teaching, diversifying chemistry education methods, encouraging students to

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experiment boldly, integrating chemistry knowledge into life, and paying attention to stimulating students' creativity and imagination, can we continuously cultivate students' abilities to discover, analyze, and solve problems, as a result, they gradually grow into innovative talents needed by the country and society.

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