



Research Article

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## Training of scientific thinking methods in teaching of inorganic and analytical chemistry

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### ABSTRACT

To adapt the demands for cultivating the target of highly-quality talents in the 21st century, the students' scientific thinking ability and innovation ability should be cultivated in the teaching. Chemistry is based on experiments, and the experiments play an important role in inquiring knowledge, mastering studying methods of science, experiencing studying process and developing the students' scientific thinking ability. The importance of the scientific thinking methods in the college classroom teaching was described in this paper. How to cultivate students' scientific thinking methods in the course Inorganic and Analytical Chemistry was mainly introduced. To stimulate the students' interest in learning, train the students' scientific thinking, and make students master the scientific experiment methods and experience study process through the reform of traditional teaching modes and contents can effectively improve the students' learning efficiency and quality.

**Key words:** scientific thinking methods; inorganic and analytical chemistry; classroom teaching

### INTRODUCTION

The 21st century is the age of knowledge economy. Today, in the explosion of knowledge and the promoting of quality education, colleges and universities should attach importance to cultivating the students' scientific thinking methods, and systematically carry out thinking training for college students, guide the students to master the correct scientific thinking methods and constantly enable the students to go beyond themselves and perfect themselves. In order to really reach the goal of cultivating the students' scientific thinking, scientific methods and scientific spirit, not only the course about scientific thinking methods should be set up but also the scientific thinking and scientific methods should be integrated into the classroom teaching to stimulate the students' interest in learning and enhance the students' innovation consciousness. To carry out innovative education, and cultivate the students' innovation consciousness, innovation spirit and innovation ability is the basic task of higher education [1].

In the optimization of the knowledge structure, the students should be subject to edification and education of scientific thinking, scientific methods, scientific spirit, engineering consciousness and engineering methods in various teaching process, so as to improve the students' comprehensive quality [2]. As a course on inorganic and analytical chemistry in the first grade of university, its teaching aim is not only to impart the basic knowledge of chemistry but more importantly to cultivate the students' abilities to obtain new knowledge and the scientific thinking methods. The students' scientific thinking ability and innovation ability can be cultivated from three aspects such as teaching thoughts, teaching contents and teaching methods.

### THE IMPORTANCE OF THE SCIENTIFIC THINKING METHODS IN THE UNIVERSITY CLASSROOM TEACHING

It is the thinking quality foundation to train the students' scientific thinking methods to form and develop the innovative consciousness and innovation ability. The scientific methods are that the generic name of finding problems, proposing hypothesis, gathering facts, analysis and demonstration, process of rethinking and so on for

people required quality and follow the ways and means in the process of scientific research, including the practice skills and methods and thinking skills and methods [3]. Paying attention to training the students' creative thinking and cultivating creative talent is the trend of modern education development. Engels said: "if a nation wants to stand in the forefront of science, even for a moment can not do without theoretical thinking." The highly differentiated and highly integrated unified characteristics for the modern times scientific research makes the mutual dependence of dialectical thinking and scientific research become more closely. The basic spirit of dialectical thinking has penetrated in modern scientific research methods. If there is a lack of the dialectical thinking methods, the scientific research can't do anything. At the same time, modern scientific research methods and achievements enrich and deepen the dialectical thinking methods, and further promote the dialectical thinking methods specific and accurate. Scientific behavior and habits, and scientific attitude, spirit and scientific values belong to non intelligence factors, and it plays a very important role for the successful cultivation of talents. The goal of scientific thinking is to reveal the nature, structure and function of the object of scientific research in the scientific research, reveal the causal relations between things and the regularity of affairs change, so as to get scientific discovery [4].

Paying attention to the training of the students' scientific thinking methods is the embodiment of the goal of quality education, and is also relying on the students' comprehensive ability development. Capabilities include thinking ability, reading ability, writing ability, experimental ability, research ability, self-learning ability and so on. Having the knowledge of people doesn't necessarily have the abilities, but the abilities of those must have knowledge. Abilities are contained in the knowledge, and letting the light of wisdom of the abilities radiated out needs to rely on the development of creative thinking methods. Lanqing Li points out: the focus of education is to teach the students to master the necessary cultural knowledge, at the same time, and teach the students to acquire the new knowledge of methods and abilities, and enable the students to apply the learned knowledge and methods and to constantly add new knowledge and solve new problems, so as to meet the needs of social development. Training students to master the scientific thinking methods so that the students have the abilities to solve practical problems is the core of quality education. Illiteracy in the future will not be without the knowledge of the people, but do not understand the scientific thinking methods and how to obtain knowledge of the people. Therefore, teachers should teach the students the methods and abilities to acquire new knowledge.

The scientific thinking methods is formed and applied in the ways and means of the scientific understanding activity and the human brain with the aid of the information and symbols on the perceptual materials processed. The scientific methods are the realization of the bridge from knowledge into abilities, and the formula is: knowledge-method-ability. The methods of scientific thinking are the key in the process of human practice, if the tool is mastered, it will greatly improve our abilities to solve various problems. To improve one's cultural quality, the first is to master the necessary basic knowledge and basic theory, the second is to master the scientific thinking methods. According to the survey, a person can only be obtained his knowledge required about 10% during the study at school, and the remaining 90% of the knowledge need to get through the learning in the future works. The students of mastering the scientific methods will be able to quickly obtain scientific knowledge, to better profoundly understand the laws of science, to comprehend the reasons the emergence and the development, to know the scientific process [5]. If a person did not learn how to learn in school, did not grasp the scientific thinking methods, it is difficult for him to have great progress and creative work in the future. In order to make the students learn to study and train the scientific thinking methods, the teachers must be good at using the holistic viewpoint and system methods, and carefully design the scheme of training the students' scientific thinking methods. The teachers need to continuously exploration, enrich and perfect how to carry out the training of the scientific thinking and the scientific literacy for the students in the basic chemistry classroom teaching [6]. How to arouse the students' interest and their creative thinking is an important issue in the instructional design of inorganic and analytical chemistry.

#### **CULTIVATION OF THE SCIENTIFIC THINKING METHODS IN THEORY TEACHING**

The traditional teaching modes and teaching contents should be reformed, so as to cultivate the students' scientific thinking and stimulate the students' interest in learning. The teaching goal of inorganic and analytical chemistry course is to guarantee the students with the abilities to analyze and solve the practical problems. Classroom teaching is not only a process of knowledge but also a process of scientific quality training. Although the traditional teaching methods are effective methods for imparting knowledge, yet only by the traditional teaching methods are unable to mobilize the students' enthusiasm. Markov Chan said: "Teach students to think, this is the most valuable thing to them in the life." Teaching students to master learning methods and scientific research skills, and guiding the student to carry on the scientific thinking, and cultivating their practical abilities to apply the possession scientific knowledge, methods and technology, and to create and discover new knowledge and open new technology, will have a far-reaching impact on the students' future work and life [7].

Teachers should be good at guiding students' thinking variation, pay attention to the students' role of independent construction of knowledge and abilities in the process of finding problems and solving the problem. As a basic

course on inorganic and analytical chemistry which are of the more course contents and less hours, it puts forward higher requirements for teachers who must constantly update the teaching contents and reform the teaching methods, the teaching means and the examination methods. The course contents of inorganic and analytical chemistry involve the basic theory of atomic and molecular structure, the basic principle of chemical reaction, the chemical equilibrium in solution, the chemical analysis, the chemical elements, conventional instrument analysis and so on. The course teaching could not exhaustive, should focus on to teach the students' the ideas and methods from the teachers understanding of the classroom teaching contents and the scientists solving the problem, make the students understand the thinking track which scientists discover and create, and learn the scientific thinking methods [8]. The teachers should reasonably and hierarchically arrange the lecture contents based on understanding the teaching materials, and should focus on the difficult and key guidance, focus on the briefly explaining and the comparative analysis, such as the four major chemical equilibrium and the four kinds of titration analysis methods. At the same time, the teachers should pay attention to introducing the subject frontier knowledge. Only while imparting knowledge, paying attention to the scientific thinking training can really improve the quality of teaching. Therefore, on teaching contents, we mainly speak on the key, the difficulties, the ideas, the methods and the applications. The interactive teaching mode of the integration of teaching and learning, namely "teaching in class, extracurricular lectures, guidance and answering, examination and evaluation", has formed. This mode not only pays attention to the cultivation of the students' scientific thinking methods, and pays attention to the training of the students' the innovation spirit and the independent learning ability.

"Learning without thought means labour lost, thought without learning is perilous." In teaching, we should not only emphasize the importance of thinking but also pay more attention to the scientific thinking methods. We should create conditions for the students in the course teaching of inorganic and analytical chemistry, let the students to reflect on the contents learned, and ask questions and thinking about the solution of the problem. Teachers should pay attention to the asking questions and the classroom discussions, let the students analyze the class information. For example, when the solubility product  $K_{sp}$  and the transformation of precipitations were introduced, and the  $K_{sp}$  values were not to give the students, we guide the students to verify the solubility of AgCl and AgI by using the experimental methods. Adding the 0.1 mol/L NaCl solution will have a white precipitate of AgCl in the 0.1 mol/L AgNO<sub>3</sub> solution. Then adding the KI solution, the white precipitate of AgCl is transformed into a yellow precipitate of AgI. But when the 0.1 mol/L NaCl solution is added to the yellow precipitate of AgI, the color of the precipitation is not changed. This indicates that AgCl precipitation can be transformed into AgI precipitation, and AgI precipitation cannot be transformed into AgCl precipitation, and the solubility of AgI is less than the solubility of AgCl. Through the knowledge of the positive teaching and the reverse experiment, the students' thinking ability has been trained.

The main functions of classroom teaching do not instill the knowledge of books, but should be the systematic interpretation of knowledge by the combination of theory and practice. The teachers should prepare lessons, and should improve the level and ability to control the classroom, and leave notes to increase the force of infection with the heuristic teaching. Inorganic and analytical chemistry course is arranged for the first grade in university. This course of study is not only in the knowledge accumulation and strengthen but also greatly improved the learning ability. We asked the students to preview before class, interact in class, summarize after class, and learn how to learn. The classroom teaching should make the students learn to thinking, learn to ask questions. We asked the students to self-study for some contents of teaching, and required the students to consult the relevant academic journals for some extension of the contents. Let the students write the small paper, discuss in class, and finally summarize by the teachers. This can stimulate the students to explore on some questions. The process of the discussion type teaching is: the teacher assigned topic, the students collected information, writing papers, the students do report, the teachers and the students ask questions, discussion, the teacher made the summary, and the evaluation of the results. Therefore, the scientific thinking and methods are introduced into classroom teaching, which help to develop the students' interest in learning, stimulate the students' scientific research potential, and enhance the students' abilities of finding problems, independently analysing practical problems and solving specific problems.

Examination is an important part of teaching which is not only helpful for inspecting the teaching quality but also an important means for examining the teaching effect. The reform of the examination methods is constantly carried out, and the cultivation of scientific thinking methods is strengthened. The students are encouraged to write the reading book report and technology "small paper". Cultivating the students' the consciousness, habit and abilities of scientific research will help the students to understand deeply the chemical knowledge and comprehensive application. Comprehensive evaluation of the final grade is composed of attendance, homework, classroom questioning, the unit test and the final exam grades. The reading report and the course paper will be extra points. The total score will be added 1 to 10 points according to the quality of writing. If it can achieve the published level the total score can be added 10 points, but no more than 100 points.

**STRENGTHEN TRAINING OF THE SCIENTIFIC THINKING METHODS IN EXPERIMENTAL TEACHING**

Chemical experiments play an important role in training students' scientific thinking methods and scientific research capability. Chemistry is a subject based on experiment, the scientific methods and scientific literacy of education to the students is particularly important use of chemical experiment teaching. It plays an irreplaceable role in chemical experiment to obtain scientific knowledge, master the scientific methods, experience with the scientific process, and culture scientific thinking ability and methods in the aspect of students. The experimental teaching can provide the experimental facts for the students to a correct understanding the matter and its changing rule, it has a purpose, exploration, reality and susceptible to intellectual. Therefore, the goal of experiment teaching should try to cultivate the students' the scientific research consciousness and the research ability, improve their skills and methods of the exploring experiment. Anbang Dai pointed out: chemical education for only teaching knowledge and technology of chemistry is one-sided, and the comprehensive chemical education not only should teach the chemical knowledge and skills, and train the scientific methods and thinking, but also should culture the scientific spirit and moral, the students are the learning subject in the chemical experiments, under the guidance of the teachers, training students solve the chemical problems through the experiments, and the intelligence of the students is all developed. The chemical experiment is one of the most effective teaching modality of chemistry education, and it can help students to establish and strengthen the chemical basic concepts and basic theories, obtain the chemical knowledge and culture the scientific quality.

The experiment is the base of chemistry teaching, and the experimental teaching can help students not only to learn the system chemistry knowledge, but also to master the scientific methods of knowledge. The formation and the development of chemical science are based on the experiments. The experiments in the chemistry teaching have provided the experimental facts which correctly understand the material properties and the change rules for the students, and each of the knowledge learned point can severally connected into the line through these facts, and then form knowledge network system. Chemistry experiment is the entry wizard and means of the knowledge of chemistry, the chemical concept is formed by the experimental facts, is rose to the chemical laws, and then is weaved the knowledge network and built the knowledge framework. This is thinking process from the outside to the inside, proceed from the one to the other, discard the dross and select the essential, eliminate the false and retain the true. In the experimental teaching, we use the heuristic teaching and the study-discuss teaching pattern, and pay attention to the cultivation of the scientific thinking methods and the research methods for the students, and cultivate the students' the logical thinking ability, innovation ability, self-learning ability and the analysis and solving question ability, and stimulate the students' the interest in learning. The teachers should guide timely the students to observe the experimental process through combining the experimental phenomena, stimulate thinking activities, and realize the leap from the perceptual stage to the rational stage. The teaching process of the chemical experiments is filled with training and exercising the students' thinking quality opportunity from first to last.

“Thinking” from “doubting”, questioning is an effective method to cultivate the students' thinking activities. The students' thinking activities are started in the urgent need of solving new problems. In the experimental teaching, the teacher should give full play to the role of questioning so that the experiment contents and the learned knowledge are of specific, systematic and problem, and inspire the students' strong desire for knowledge so that the students always maintain effective and active thinking. For example, entitled “preparation of the ammonium ferrous sulfate experiment”, the experiment must be carried out in a fume hood, but the entire laboratory can still smell the stench. Compared with the green chemical requirements, the preparation experiment of ammonium ferrous sulfate has the following two shortcomings: the first is the exhaust gas to be governance, and the second is the rational utilization of the raw materials which has not reached the maximum. The students take these problems into consideration, and improve the experiment with the idea of green chemistry. This can not only improve the students' the learning interest and consolidate the learned knowledge, but also cultivate the students' independent thinking ability. The experimental device is closed by the improvement. Because of the iron impurity, the H<sub>2</sub>S and SO<sub>2</sub> waste gas which generated in the preparation reaction is recycled by the alkali liquor bottle. After the improved device, the experiment is not performed in a fume hood, but we don't smell the stench [9]. Therefore, improving the preparation experiment of ammonium ferrous sulfate is the concrete application of the guiding ideology of green chemistry. This will help to develop the students' environmental protection awareness, and establish the full utilization of resources, and implement the green chemical technology thought. At the same time, the students become practitioners of green chemistry to lay the foundation in the future experiments, the graduation thesis designing and future work.

The reform of the course system and the experimental contents of inorganic and analytical chemistry experiment should start with training the students' scientific thinking, mastering scientific experimental methods and improving the students' comprehensive practical ability and innovation consciousness, and the experimental teaching system and experiment teaching contents should be gradually optimized and improved. Strengthening the green chemistry education, reforming the traditional chemical experiment contents, and implementing the green chemical

experiment in chemistry experimental teaching is to represent the general trend, this is also the specific application of the scientific thinking methods in experiment teaching reform. How to put the idea of green chemistry in university chemistry teaching, and reduce environmental pollution in the chemical experiment, enhance the students' awareness of environmental protection, is an important part of the chemical education, and is also a new topic of chemical experimental teaching reform. The establishment and improvement of green inorganic and analytical chemistry experiment system will be advantageous to the related professional university freshmen firmly establishing the green chemical concept and the environmental protection consciousness. Thus, the students consciously use to lay a solid foundation for these methods in future.

From the experiences of experimental teaching reforms, looking for substitutes, implementing the micro experiment, developing the sealed experiment and series experiment, empoldering simulated experiment, and recycling experiment products are an important way to realize the green inorganic and analytical chemistry experiment. For example, the product of the preparation experiment of ammonium ferrous sulfate can be used as raw material for synthesis of  $K_3[Fe(C_2O_4)_3]$ . Therefore, abandoning the heavily-polluted traditional chemical experiments and exploring of the green transformation of chemical experiment is the direction of the struggle of chemistry experiment educators. In the inorganic and analytical chemistry experiment teaching, we pay attention to innovation based on inheriting the traditional contents, increase the design experiment, strengthen comprehensive experiment, and reduce the verification experiment. Through the integration of the original experimental project, the contents of experiment teaching system have been the overall optimization. In teaching, we pay attention to cultivating the students' awareness of environmental protection, instill the concept of green chemistry, actively carry out the research of the green chemistry experiment, and promote the green chemistry experiment teaching.

According to the characteristics of inorganic and analytical chemistry experiment, the traditional chemical experiments have been carried out the transformation with the green chemistry concept, and the miniaturization preparation experiments, reduction analytical chemistry experiments and green experimental contents have been established [10]. Such as the titration analysis experiment, the concentration of standard solution is reduced from 0.1 mol/L to 0.01 or 0.02 mol/L, burette is changed to 25 mL, and the conical flask is replaced by 100 mL [11]. Because the reagent consumption is greatly reduced, the safety of experiments is improved. Because the "three wastes" the quantity is very few, the environmental conditions are improved and the environmental pollution is greatly reduced. The teaching of inorganic and analytical chemistry experiment can be completed in conventional instruments, and it can not only reduce the number of chemical reagents consumption and save the experimental cost but also strengthen the students' consciousness of environmental protection.

The designing ability of chemical experiment is a good training form for students' scientific thinking methods and ability. The chemical experiment design is based on the problem and the condition to design the experimental plans of the solving problem, through the use of chemical experiment methods learned, the students can be the correct choice and use of laboratory equipments, and can confirm or adjust the experimental steps, capture the relevant information, and analyze the experimental results. For example, we require the students to design a scheme entitled "synthesis and characterization of zinc glycinate chelate". The chemical experimental designs can make the students play the subjective role in experiment teaching, and encourage the students to do the experimental host, and avoid the students to do passively experiment. The chemical experimental designs require that the students can flexibly and creatively use the chemical basic knowledge and skills learned. These provide a good environment and conditions for the development of the scientific thinking methods and ability. The improvement of scientific thinking ability is not a simple inculcation, but the individual internalization and sublimation process in the independent study and practice. The experimental study of the independent subject can give full play to the students' subjective role and status, and makes the students' scientific thinking ability improve continuously in practice [12].

In a word, through the teaching of inorganic and analytical chemistry experiment, the teachers should guide the students to habitually discover scientific problems, induce the students' thinking variation, pay attention to the students' role in independent construction of knowledge and abilities in the process of putting forward questions, thinking and solving problems, cultivate and improve the students' the level and ability of scientific thinking methods. Experimental teaching plays an important role which cannot be replaced by theory teaching and it is the important way of quality-oriented education and promoting the conversion of knowledge and abilities.

## CONCLUSION

College should reform its education methods and guide the students to develop scientific thinking methods. As an experimentation of teaching reform, we put the scientific thinking mode in the teaching process of the inorganic and analytical chemistry curriculum, consciously cultivate the undergraduates to master the scientific thinking methods, and make the students form a good habit of scientific thinking. This method of teaching can not only stimulate the

students' interest in learning and improve the teaching effect but also cultivate the students' self-study ability and innovative ability. This can enable them to consciously use various scientific thinking methods in the subsequent course and future work, so as to improve the comprehensive abilities of solving problems.

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