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Exploration of the Cultivation Model of Science and Technology Competition Project for Chemistry Majors under Undergraduate Tutorial System

Qingqing Lu, Furui Ma, Libin Liu*

School of Chemistry and Chemical Engineering, Qilu University of Technology (Shandong Academy of Sciences), Jinan 250353, China

* Corresponding author: lbliu@qlu.edu.cn

Abstract

Under the background of the construction of new engineering disciplines, optimizing and reforming the mechanism for cultivating innovative talents is of great significance for improving the quality of talent cultivation. The "tutorial system" for undergraduate students majoring in chemistry is an important way to implement "teaching according to students' aptitude" and develop their personality and expertise. The undergraduate tutorial system based on science and technology competition platforms has important practical significance for improving students' self-learning ability, hands-on practical ability, and enhancing the quality of talent cultivation in universities. This article discusses the implementation of the "tutorial system" for undergraduate students in various universities and the common problems in "science and technology competition cultivation". It explores how to rely on the "tutorial system" to cultivate high-quality chemistry science and technology competition projects and innovative talents.

Keywords

Tutorial System, Chemistry Majors, Science and Technology Competition.

1. Introduction

In recent years, universities have been actively seeking ways to cultivate innovative talents, and science and technology competitions have become an important means to guide the reform of higher education. The awards of undergraduate students in various competitions are also an important component of evaluating the level of undergraduate education and teaching in universities. The level of scientific research and technological innovation capability are important indicators for measuring the level of education and social influence of a university. The tutorial system is an effective way to enhance the scientific research level of universities and cultivate students' innovative abilities. Organically combining the "tutorial system" with "science and technology competitions", utilizing the rich social experience and profound professional knowledge of mentors to tailor teaching to each student's personality, cultivating students' ability to independently analyze and solve problems, and ultimately achieving comprehensive and personalized cultivation of students' thinking, learning, and other aspects; The flexible talent cultivation model of mentorship is suitable for the platform of science and technology competitions and can effectively promote the common development of teachers, students, and majors. However, the current effectiveness of cultivating science and technology competition projects under the tutorial system is not significant, lacking effective supervision and evaluation mechanisms, teacher-student mutual selection policies, and supporting incentive mechanisms.

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2. The Research Status and Significance of Undergraduate Tutorial System

In recent years, with the increasing call for personalized education reform that puts people first, the undergraduate "tutorial system" has emerged as a new model of undergraduate education reform in domestic higher education institutions to build quality education and cultivate innovative talents [1]. A large number of domestic prestigious universities have begun to explore and practice the "undergraduate tutorial system". Since 2002, universities such as Peking University and Zhejiang University have attempted to implement a tutorial system among undergraduate students, which has gradually been implemented in various universities. From the implementation of the tutorial system, nearly 100 universities across the country are currently piloting the tutorial system. Unlike the graduate tutorial system, the undergraduate tutorial system refers to an educational system in which teachers provide individual guidance on undergraduate students' learning, morality, ideology, employment, and other aspects through words and deeds, in order to improve students' comprehensive qualities such as ideological and moral level, scientific and cultural level, and scientific research and innovation ability. Although the implementation types, stages, and effects of each school and college are different, their respective effects are constantly emerging, and the quality of undergraduate education is steadily improving.

Chemistry is a natural discipline based on experiments, and the chemistry majors in university aim to cultivate advanced professionals with basic knowledge, theories, and skills in chemistry, who can engage in scientific research, teaching, and related management work in chemistry and related scientific and technological fields. At present, the demand for talents in the chemical industry is constantly increasing, which puts forward new requirements for the talent cultivation mode of higher education in China. Traditional education often focuses on imparting textbook knowledge. Under this model, college graduates have a good reserve of professional knowledge, but their practical and innovative abilities in scientific research are clearly lacking. In the fourth year graduation thesis stage, although undergraduate students can participate in a certain amount of scientific research work to a certain extent, most of them can only conduct basic experimental operations or simple mechanical data input and processing, and cannot deeply analyze experimental results, let alone explore the novelty of the topic. This seriously affects the enthusiasm of undergraduate students for scientific research work. Therefore, unlike most other majors, the undergraduate tutorial system for chemistry majors aims to combine with the construction of research teams, fully tap into the research potential of undergraduate students, focus on developing their innovative thinking, and fully tap into their independent thinking and practical skills. This not only improves students' technological innovation ability, but also benefits the enhancement of the school's research power.

At present, there are still some problems in the operation of undergraduate tutorial system, such as unclear positioning and unclear responsibilities. Bingqi Xiong, a professor at Shanghai Jiao Tong University and vice president of the 21st Century Education Research Institute, pointed out that "currently, the tutorial system at the undergraduate level in China is only conceptual rather than substantive. Many universities do not implement a true tutorial system, and there is a common situation of “mentors do not guide””. In addition, when assigning mentors to undergraduate students, most of them are randomly assigned. This kind of teacher-student combination can easily lead to students being uninterested in the mentor's major and research topic, and even different disciplines and majors, resulting in poor communication between teachers and students, and the effect of "guidance" is not obvious. Furthermore, many universities consider the work of mentoring teachers as a duty and dedication, with incomplete incentive measures and generally low compensation. Many research and teaching backbones are unwilling to serve as undergraduate mentors due to time and energy constraints, which affects the overall quality of mentors. At present, the number of students in ordinary

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universities across our country exceeds 40 million, with a teacher-student ratio of about 1:17, which is not conducive to full communication between mentors and each student, and cannot truly reflect the superiority and personalized characteristics of the "tutorial system". In the United States, Stanford has a teacher-student ratio of 1:3 and Princeton has a teacher-student ratio of 1:6. These prestigious universities regard quality as life and strictly control student number to maintain an ideal teacher-student ratio.

In terms of supervision and evaluation system, Oxford University implements a "personalized and flexible evaluation and supervision mechanism", which means that the workload of the supervisor for one academic year is fixed, but there are no strict regulations on the specific form, time, and location of the supervisor's lectures, and the supervisor enjoys considerable autonomy. At the same time, the supervisor is required to provide a written report on the students' progress at the end of the semester. By comparison, it seems that domestic universities do not have a clear assessment mechanism for the responsibilities of undergraduate supervisors.

3. The Current Situation and Significance of Participating in Science and Technology Competition for Undergraduates Majoring in Chemistry

The cultivation of college students' innovation ability is the key to cultivating qualified college students, and science and technology competitions can be an important way to cultivate and enhance college students' innovation ability. The science and technology competitions have a significant impact on the establishment, cultivation, exercise, and improvement of students' scientific thinking.

Nowadays, there are various types of science and technology competitions for undergraduates majoring in chemistry, including the "Challenge Cup", "China International College Student Innovation Competition", "National College Student Chemistry Experiment Competition", "National College Student Energy Conservation and Emission Reduction Competition", etc. By participating in chemical science and technology competitions, students can directly participate in designing and implementing experiments, completing a complete scientific research process from literature review, experimental design, experimental operation, data analysis and processing, and writing and presentation of research results. This not only consolidates basic knowledge, familiarizes students with the principles and usage methods of instrument analysis, but also exercises and improves their ability to analyze and solve problems. At the same time, the science and technology competitions often involves topics with a certain depth and multidisciplinary background, which requires personalized learning from students' strengths and weaknesses, division of labor and cooperation, and tacit cooperation, in order to cultivate students' team consciousness and teamwork spirit. In addition, promoting and commending outstanding students in competitions can help create a good learning atmosphere, stimulate students' interest and motivation in learning, and achieve the goal of promoting teaching and learning atmosphere through competitions.

A survey found that the management, teachers, and students of some universities have a relatively limited understanding of college students' science and technology competitions. Some even believe that college students should focus on professional learning, and that science and technology competition activities are just campus culture for college students to participate in. Overall, with the introduction of various incentive mechanisms such as admission bonus points and scholarship evaluation bonus points by major universities, the willingness of undergraduate students to participate in technology competitions has increased. However, the results of technology competitions are often unsatisfactory. This can mainly be attributed to the following factors: firstly, the chemistry major is still mainly based on theoretical teaching, supplemented by basic experimental teaching. Students have many class hours, heavy learning

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tasks, and limited time and energy to self-manage and use for scientific research competitions [2]. Freshman students have enthusiasm, but they don't know how to start scientific research. They only start studying professional courses in their sophomore year, prepare for postgraduate entrance exams in their junior year, and face graduation in their senior year; Secondly, students have a high enthusiasm for participating in technology competition projects, but their sustainability is relatively short and their utilitarianism is strong. They can truly enter the laboratory to learn skills and achieve results through accumulation bit by bit. There are fewer students participating in the competition, and there are more breakthroughs in technology achievements than those who truly conduct their own research. Science and technology competition activities require strong spiritual motivation and clear goals, and cannot rely solely on "temporary courage". It is necessary to "establish long-term aspirations" and not "always aspire to"; Again, university teachers generally face heavy teaching and research assessment tasks, guiding college students, especially those with no research foundation, to participate in competitions, which can be physically and mentally exhausting; Fourthly, the benefits of the competition are relatively narrow. Many participating teams from universities follow the "key selection, targeted training" model, where the school selects a small group of student elites for targeted training, and then participates in the competition through repeated training. In this mode, the competition has evolved into a performance stage for a few elite individuals, while the majority of students remain spectators. Finally, at present, the number of students in ordinary universities across the country exceeds 40 million, with a teacher-student ratio of about 1:17. Such a low teacher-student ratio makes it difficult to increase teachers' participation in science and technology competitions.

In recent years, in order to better promote the development of college students' innovation ability through science and technology competitions, Qilu University of Technology (Shandong Academy of Sciences) has reformed its teaching plan, teaching content, and the mode of obtaining credits through exams in a targeted manner. It has also implemented a flexible credit system for internships, set up new training programs such as innovative credits, and implemented hierarchical and classified education reforms. In addition, the school has introduced various bonus points and scholarship selection measures to encourage students to participate in various science and technology competition projects, and has listed the guidance of students to win competitions as one of the necessary conditions for teacher evaluation and appointment.

On the foreign front, the Massachusetts Institute of Technology (MIT) in the United States established the "Undergraduate Research Opportunity Program" as early as the 1960s, encouraging and supporting undergraduate students who meet certain conditions to participate in teachers' scientific research projects. The University of California, Los Angeles also began systematically supporting undergraduate participation in scientific research in the 1980s. Currently, the school has established two "Undergraduate Research Centers" under the categories of humanities and social sciences, and life and material sciences. The guided research program offered by Yale University for some first-year students is also highly competitive for selection. The German University of Applied Sciences strengthens the training of engineering practice and technological innovation abilities for college students, focuses on the application of scientific and technological knowledge, imparts broad knowledge including skills and abilities on how to transform a creative idea into a competitive product, and cultivates a large number of high-level applied talents with engineering qualifications.

At present, the development of science and technology competitions for college students in various universities is unbalanced and still in the exploratory stage. How to guide college students to engage in technological innovation and cultivate talents with innovative thinking and abilities is an important issue facing universities under the new situation.

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4. Measures and Significance of Cultivating Science and Technology Competition Projects for Chemistry Majors under Undergraduate Tutorial System

The science and technology competition provides a powerful platform for the undergraduate tutorial system, as well as a driving force for innovation and development for college students [3]. At present, many universities have gradually implemented the undergraduate tutorial system, including encouraging students to participate in various science and technology competitions. However, there are few that organically combine the "tutorial system" with "guiding students to carry out science and technology competition projects", and even fewer that can be included in the standardized management track. By fully tapping into and stimulating students' initiative and creativity in academic research, and encouraging students to join mentor research teams, the "tutorial system" is conducive to cultivating more high-level science and technology competition projects.

On the one hand, most of the students participating in the competition are in the second and third grades, and their mastery and understanding of professional knowledge are still at a relatively low level. It is very difficult for them to achieve a certain degree of innovation. However, when participating in various science and technology competitions, the innovation level of the project is the most important assessment standard. Through the undergraduate "tutorial system", the guiding teacher decomposes national or provincial major research projects with a certain research foundation into corresponding sub projects, and provides the opportunity to participate in high-level cutting-edge projects as well as conducts targeted research on relevant domestic and foreign literature. This undoubtedly enhances their research starting point and offers a guarantee for the final victory of science and technology competitions.

On the other hand, under the guidance of the tutorial system, students follow their mentors to participate in practical research projects. Through literature reading, scientific experiments, result discussions, and reports, they start preparing for academic research early on. With the deep and effective guidance of their mentors, they write and submit research papers, apply for invention patents, and lay a solid theoretical foundation for science and technology competitions.

Chemistry is a highly practical discipline, and mentors should not only provide general theoretical guidance to students, but also combine practical research projects to comprehensively cultivate students from both theoretical and practical aspects. Therefore, using science and technology competitions as a carrier and integrating them into the undergraduate tutorial system is beneficial for mentors to cultivate and guide students to participate in various science and technology competitions in a targeted manner, teach students according to their aptitude, fully respect the personality of college students and give full play to their strengths, improve the problem of mentors lacking goals and focus in the process of student guidance, and enable students to receive substantial guidance, thus forming a new teaching model of "using competitions to promote teaching, learning, and education". The specific measures for cultivating high-quality technology competition projects for college students under the "tutorial system" are as follows:

4.1. Establish and Improve Competition Incentive Mechanisms

A survey shows that a large part of students' motivation for participating in the competition is due to policies such as bonus points and awards, which link students' various innovative achievements with various scholarship evaluations, awards, etc. According to the awards received by students at different levels, different levels of credits or material rewards are given. Encouragement awards are also given to students who actively participate in the competition,

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making the science and technology competition move towards a sustainable and virtuous cycle trajectory; In the construction of the mentor team, the participation results of guiding students will be included in the assessment scope of professional title evaluation to fully mobilize the enthusiasm of guiding teachers.

4.2. Reforming the Undergraduate Education Model

In order to better promote the development of college students' innovation ability through science and technology competitions, targeted reforms have been made to teaching plans, teaching content, and the mode of obtaining credits through exams [4]. A flexible credit system has been implemented, and new training programs such as innovative credits and hierarchical classification education reform have been established. Incorporating undergraduate laboratory research practices based on science and technology competitions into the teaching plan and earning certain credits not only solves the problem of science and technology competitions being just a second classroom for college students, but also addresses the issue of low participation ratios in scientific research activities. At the same time, it lays the foundation for conducting science and technology competition activities. Professional mentors can also make slight modifications to the competition questions according to teaching needs and introduce them into classroom teaching or as experimental teaching content, so that the competition concept can gradually permeate into students' daily learning, stimulate students' interest in participating, and make innovative ideas deeply rooted in people's hearts.

4.3. Optimizing the Tutorial Team

The survey found that the higher the interest of the mentor's project, the closer it is to the students' reality, and the higher the students' enthusiasm for participating in science and technology competition projects, they will be willing to invest more energy and enhance the innovation motivation of innovators. The high level of the guidance teacher team is directly related to the quality of talent cultivation through competition. It is necessary to optimize the construction of the guidance teacher team in the "tutorial system", fully play the leading role of guidance teachers in science and technology competitions, and fully play the role of experienced "old" teachers in "transmission, assistance, and guidance", absorb some excellent young teachers to join, and establish a high-quality and high-level guidance team.

Taking Qilu University of Technology (Shandong Academy of Sciences) as an example, in recent years, it has actively implemented an undergraduate training mechanism that integrates the "tutorial system" and "cultivation of science and technology competition projects", cultivating numerous high-quality science and technology competition projects and winning multiple gold awards in domestic and even international competitions, significantly improving the reputation of the university. The school provides academic mentors for each undergraduate student, who is responsible for their professional education, course selection guidance, promotion of academic credit system, academic warning, and career planning. Academic mentors mainly provide individual guidance and combine individual guidance with collective guidance. They meet with students at the beginning of each semester, participate in student collective activities, hold student symposiums, or give lectures to students no less than three times per semester. In addition, the Department of Chemistry at the School of Chemistry and Chemical Engineering has been implementing a mentorship training model for undergraduate students since the class of 2018. Each undergraduate student is assigned one research supervisor, and each supervisor is required to guide a total of no more than four students. Students are required to complete training such as "Science and Technology Competitions" under the guidance of their supervisors. Students are required to participate in school level and above competitions as the first participant and earn corresponding credits. Through the curriculum, students are able to flexibly apply basic chemical knowledge, master the ability to search for information, give speeches and defend, and adapt to changing situations, laying a solid foundation for their future

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scientific research work. Based on this, many chemistry majors such as Yaning Zhang and Rumeng Yin have won the national bronze award of the "Challenge Cup", the national gold award of the "China International College Student Innovation Competition", and the first prize of the "National College Student Chemistry Experiment Competition".

5. Conclusion

With the popularization of higher education, college students have become the main force of social innovation, and the country urgently needs high-quality talents to promote economic and social development. Cultivating the innovation ability of college students has also become one of the main tasks of higher education. Among the many ways to cultivate innovation ability, relying on the tutorial system to participate in technology competitions to cultivate innovation awareness and enhance innovation ability is also a relatively efficient method. There are many benefits to technology competitions, but there are still certain problems. School education should avoid excessive technology competitions and neglect normal teaching. Students' attitudes towards technology competitions should not be too utilitarian. They should adjust their own attitudes and face challenges and breakthroughs with the correct mindset, so that technology competitions can play the greatest role in cultivating innovation ability. Each university needs to combine its own development characteristics with the needs of the talent market, encourage students to actively participate in science and technology competitions, continuously explore and improve the mentorship management system, and cultivate innovative and comprehensive talents that adapt to social development.

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