Exploration of enlightenment experiments for green chemical engineering talents in China higher education - taking Sichuan University as an example

Shun Yao[1], *Yu* Cao[2], and *Shengwei* Tang[1,*]

[1]School of Chemical Engineering, Sichuan University, 610065 Chengdu, China
[2]College of Life Science & Biotechnology, Mianyang Teachers'College, Mianyang 621000, China

Abstract. How to lead green industry education and promote the development of sustainable society is an urgent issue to be explored. In order to effectively promote the recognition and disciplinary enlightenment of green chemical engineering among involved freshmen in Sichuan University, we designed a set of modular experiments using green solvents and zebrafish as carriers for observation and practice, which emphasized the importance and necessity of green engineering technology, as well as the significance of biomedicine for human health. Its implementation not only helps guide students to establish correct concepts of related specialty and industry, but also effectively stimulates their interest in learning and researching. Through continuous improvement, it is expected to be promoted as a public open experiment in wider range.

1 Introduction

In modern chemical engineering production, people have innovatively proposed the ecological concept of green environmental protection, and hope that in future chemical engineering, new green environmental protection concepts can be continuously applied and innovated, promoting the rapid development of contemporary chemical engineering projects [1,2]. In a simple word, green chemical technology refers to the improvement of existing chemical engineering technologies through scientific and effective measures, such as improving the way chemical reactions are carried out, in order to reduce the generation of waste in chemical industry production, reduce pollutant emissions, and prevent damage to the natural environment caused by chemical process production [3].

In response to the challenges from resources and environment in human society, higher educational institutions should actively respond to the call for national ecological civilization and green society construction, and focus on exploring new educational models that integrate the concept of green engineering education into talent cultivation [4]. How to lead green industry education and promote the development of chemical engineering is an urgent issue to be explored. It is conducive to accelerating the cultivation of comprehensive

* Corresponding author: tangdynasty@scu.edu.cn

talents for the future, thereby enhancing the comprehensive strength of China's chemical education and research infrastructure, and contributing wisdom and strength to support national development strategies and needs. Relevant high-level talents will lead the development of the green chemical industry system and better serve basic research, new technologies, and industrial innovation [5.6].

The School of Chemical Engineering at Sichuan University has majors in Green Chemical Engineering and Biomedicine, with an annual enrollment ranking almost among the top in engineering majors. However, due to misunderstandings about chemistry and chemical engineering in the whole society, the number of first-choice students enrolled is not high, and their interest in learning is also affected to some extent. Many people believe that chemistry runs counter to green society and is a producer of pollution at present. Such erroneous ideas urgently need to be corrected, but the current classroom methods are relatively limited, and ordinary preaching is difficult to resonate with students, nor can it stimulate the learning interest and professional identity of new students.

Through the feedback from the freshman seminar and class meeting, most students are interested in experimental animals. Based on this, this study carefully selected zebrafish as the experimental object, which is a model animal and its involved experiments are simple, safe, intuitive, easy to operate, and highly practical; so it is very suitable for lower grade students with a low reserve of introductory knowledge and experimental requirements. With the goal of guiding them to have a correct understanding of the subject, stimulating learning interest, and laying a foundation for professional learning, this project takes the specialty introduction after enrollment as the starting point, and leads all professional students to explore and recognize the highly concerned and frequently reflected issues such as "whether chemistry threatens the human health and environment", "what is a green solvent", and "the magical performance of herbs" in the designated practice and demonstration experimental activities.

2. Experiments and practical activities design

Considering that the freshmen only have the basic skills and common sense of ordinary chemistry and biology experiments in middle school, the teachers provided reading materials for students to have a preliminary understanding before this practical activity. During the activities, simple training was carried out collectively, and some operations with high requirements were mainly demonstrated by the teachers and observed by the students. Full communication, feedback, and discussion were conducted throughout the entire process. Both the teacher and students completed the recording of the content of these activities, which would be used for systematic evaluation for actual effect. **Fig. 1** includes the main contents of this project.

2.1. Synthesis of green solvents and preliminary evaluation

In order to ensure the safety of the experiment and fully reflect the green nature of the following organic medium, a series of deep eutectic solvents (DES) were selected as the experimental object, which belong to a kind of new green solvent composed of two or more substances mixed in a certain proportion [7], with a melting point significantly lower than that of each single component. It can be directly prepared from natural ingredients without the need for special skills and equipment, and the whole precess is very simple and friendly. Specifically, edible grade glycerol or xylitol with proline or lysine were mixed in a certain proportion, and the mixture continued to be heated and stirred until a transparent and homogeneous liquid was formed. The obtained product was tested for its acidity and alkalinity using pH test paper, and its irritation was also observed by applying it to exposed skin. Qualitative and purity analysis was then conducted using spectroscopy.

Fig. 1. The design scheme of the whole process composed of three modular experiments.

2.2. Acute toxicity experiment of zebrafish

The zebrafish with a body length of 2.0 ± 1cm was domesticated in fully aerated pure water for 7 days, and fasted from 24 hours before the start of the experiment to the end of the experiment. Under specified conditions, expose fish to aqueous solutions containing different concentrations of test substances (green solvents and heavy metal control substances). Record the mortality rate of experimental fish every 6 hours within an experimental cycle, calculate the concentration of the test substance LC50 (the concentration of half of the dead fish at a certain time point) when the fish mortality rate reaches 50%, and determine the acute toxicity level. Finally, dissect the dead zebrafish; Starting from the zebrafish's abdominal fins with a blade, use a scalpel to cut open the zebrafish's abdomen to its head, and observe its internal organs and tissues through a microscope. The specific experimental methods refer to the "Acute Toxicity Test Method for Fish" of the Organization for Economic Cooperation and Development (OECD) and the Chinese national standard GB/T 13267-91 "Method for Determining the Acute Toxicity of Water Quality Substances to Freshwater Fish (Zebrafish)".

2.3. Anti hypoxia effect of Salvia miltiorrhiza (Danshen) extract on zebrafish

Through existing research, *Salvia miltiorrhiza* (Danshen) extract has anti hypoxic effect, which is commonly used in the treatment of cardiovascular diseases in clinical practice. An appropriate amount of Danshen powders (60 mesh) was first weighed, then extracted with ethanol or DES under the same conditions; after extraction, the extract was filtered and the filtrate was collected, and the extraction efficiency was determined. The students removed the fish from the fish tank, observed the hypoxia status of the fish, and recorded it. After that, they placed the anoxic fish in a beaker filled with 50 mL pure water, added two kinds of extracts of *Salvia miltiorrhiza* dropwisely. The recovery process of the fish was observed; relevant experimental data and images were recorded, which were compared with anatomical and microscopic analysis results. For those fish that were restored to normal after adding *salvia miltiorrhiza* extract, they were subjected to secondary hypoxia after 15 min. Then they were placed in pure water to observe their status after re entry, and compared with the control group without adding *Salvia miltiorrhiza* extract.

3 Results and discussions

3.1. Overall evaluation and feedback

Throughout the entire activity, there was close collaboration between teachers and students, as well as between teaching and learning. At the same time, it also integrates various teaching modes such as "learning by doing" and "flipped classroom". Through a week long experiment and practical activities, the following results have been obtained: (1) more than half of the freshmen have mastered at least one important experimental skill; (2) they have a basic understanding of the physiological activity characteristics and body structure of zebrafish; (3) more than 70% of students have a genuine understanding of the importance and practicality of green chemical engineering. Regardless of which major they pursue in the future, they have decided to take action and do their best to correct the misunderstanding of chemical engineering from the society; (4) they hope to conduct zebrafish experiments again in senior professional experiments and expand the current experimental content; (5) almost all students began to pay attention to the impact of industry on the environment and their concern for water quality; (6) students who choose to continue their studies in the biomedicine field are beginning to pay attention to other animal experiments used for activity evaluation.

3.2. Training and improvement

Before the activity started, most students are not familiar with green chemistry and chemical engineering, nor are they familiar with biomedicine, and even have no concept of what zebrafish and low melting solvents are. They only received basic skill training and experimental safety education in middle school; but in this project, they demonstrated a strong interest and desire for knowledge. After reading the learning files distributed by the teacher before the experiments, they were encouraged to collect more knowledge and information related to this project in the library and online, so that their self-learning ability and literature retrieval ability began to take off. Generally, these abilities need to be trained in higher grade public courses. After marveling at the gradual transformation of solid mixtures into liquids, they learned simple methods for preliminary characterization of unknown substances and were able to understand the deep eutectic phenomenon with the help of the teacher's answers, which actually exists in daily life. Moreover, many students may not be unfamiliar with the structure and lifestyle of edible fishes, but it is the first time to dissect and observe such a small zebrafish microscopically, which requires the guidance and advice of teachers. They further learned that extracting active substances can separate them from the raw material matrix, who also developed the concept of creating animal models. When they discovered that extracts from herbs could quickly revive a dying zebrafish, they were greatly shocked and had a strong interest in the subject. This intuitive firsthand experience far surpasses simple preaching and ordinary science popularization.

3.3. Analysis and reformation

During the implementation of this project, the teachers gave a comprehensive rating based on the students' previews (20%), on-site communication (20%), experimental operations (30%), and final report (30%). The number of assessors was 102, with an average score of 86.9, the highest score of 96, and the lowest score of 60. The majority of students with a score of over 90, accounting for 46%; next is the score range of 80-89, accounting for 43%. In addition, there are no individuals who fail the assessment. The above results indicate that, on the one hand, new students have a high enthusiasm for learning and are able to complete this practical activity well; Secondly, the content and stages of this project design are suitable for them, with moderate difficulty and high completion rate; Finally, it should be noted that the students have a good foundation, which is a good guarantee for entering the higher grades of professional learning.

After the event, we invited all the students present to use their mobile phones to conduct a satisfaction evaluation, and also invited the teachers and members of the college's teaching supervision team who participated in the whole procedures to complete the synchronous evaluation. It can be found more than 77% teachers and students felt very satisfied for the project. Besides that, specific suggestions and opinions were directly collected for those aspects that need improvement or dissatisfaction, which mainly included: (1) the overall practical content is a little extensive, but time is relatively short; (2) the number of practice equipments can be more; (3) some short videos were suggested to be combined with these activities; (4) the behavioral indicators of zebrafish need to be quantified; (5) this project can serve as a public open experiment for all students in the university, etc. The teachers of our teaching and research group conducted a serious analysis and discussion on these problems, and exchanged ideas in depth with the representatives of students together with the teaching supervision group. The relevant content has been compiled into a detailed teaching reflection report, which also points out the direction for the next step of general enlightenment education for green chemical engineering. **Fig. 2** summarized the key data about above analysis and feedback.

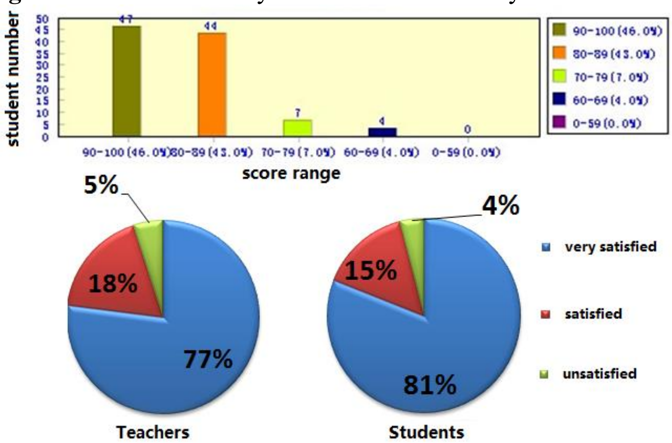

Fig. 2. Histogram analysis of scoring results and feedback from teachers (n=12) and students (n=102).

4 Conclusions and outlook

In summary, this study provides a beneficial supplement to the existing teaching experimental system and related contents, introduced new elements and methods, conducted the most intuitive science popularization through practical activities, and countered the existing incorrect guidance. It has laid a preliminary foundation for senior professional learning. In a series of teaching and research activities spanning two years, including design, preparation, implementation, feedback, analysis, reflection, and improvement, this study has achieved the following goals:

(1) By organizing project team teachers to discuss and develop practical activity plans related to this study, we clarify the content of practical activities, and build an feasible experimental platform;

(2) In the autumn semester of freshman enrollment, relevant knowledge was promoted and popularized to professional students in combination with the classroom, and the awareness of green chemical engineering was strengthened. Practical activities were carried out according to the established plan for trial operation, and the established practical tasks were completed one by one.

(3) The project team completed two rounds of inspections by the Academic Affairs Office of Sichuan University and the School of Chemical Engineering, summarizing the project progress, existing problems, goal achievement, and comprehensive feedback.

(4) The project team will focus on discussing and evaluating the effectiveness of practical activities, and establish a more scientifically sound assessment and evaluation system.

(5) The construction of a more comprehensive zebrafish practice platform are in progress, we are striving to incorporate it into the public experimental system and the Chengdu Classroom Science Popularization Project Platform, and then expand the audience to primary and secondary school students and the general public.

From the current perspective, green chemical engineering is bound to be the future direction for the transformation and upgrading of traditional chemical engineering. Integrating the concept of green development into chemical engineering education and enhancing the green engineering ability of chemical engineering students has become an inevitable trend. Green engineering education integrates knowledge and thinking from multiple disciplines such as ecological civilization, humanities, philosophy, and social sciences [8]. The prerequisite for achieving green chemical engineering is to cultivate chemical engineering professionals with green engineering capabilities. Faced with the significant opportunities and challenges brought by the global new round of industrial and technological revolution, more innovative talent cultivation methods similar to this project are worth looking forward to.

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