Improvement of Cultivation Quality of Future Environmental Protection Talents: from Scientific Literacy Aspects

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Abstract: In recent years, as the development of environment science, new demands are needed for the cultivation of environmental protection talents. The improvement of scientific literacy has become an urgent need in the cultivation of undergraduate students major in environmental science and engineering. A good talent training model can promote the output of environmental protection talents and support the future environmental construction. In this paper, authors introduced the settings and practice of “Environmental Microbiology Practice” (EMP) in Miami College of Henan University. The teaching group of Miami College believed that EMP is the most suitable teaching link to help undergraduates understand the frontiers of the subject and improve scientific research thinking and did a series of reforms on the EMP course around (1) Current microbiological industry practice; (2) Frontier expansion of environmental microbiology; (3) Cultivation of scientific literacy. Combined with the students’ achievements and a questionnaire, the effectiveness of EMP has also been analyzed. By analyzing the practice of EMP in Miami College, this study provided an effective way for the improvement of scientific literacy and quality of undergraduate students. This cultivation idea and method is also of great significance for the cultivation of reserve talents of environmental protection who meet the needs of environmental scientific research and environmental protection in the new era.

1. Introduction

With the development of time, the environmental protection business has put forward new requirements for talents. As an important source of reserve talents for environmental protection, the current undergraduate education is faced with great innovation and development opportunities. With the deterioration of ecological environment and the application of microbial treatment, the research and application of microorganisms in environmental science and engineering are deepening[1]. In recent years, “Environmental Microbiology” has gradually become one of the important courses in undergraduate teaching of Environmental Science and Engineering. The setting of this course is of great significance to the improvement of undergraduates’ ability of environmental science research and the cultivation of future environmental protection talents. This course has the characterized by extensive knowledge, relatively trivial knowledge points, strong theory and practicality. In order to guarantee the quality of this curriculum, colleges and universities generally adopt a combination of theoretical teaching, experimental teaching and practical teaching to help students not only learn disciplinary theories but also master experimental skills and improve their ability to solve practical problems.

As an important supplement to the course of Environmental Microbiology, Environmental
Microbiology Practice (EMP) aims to enable students to master the following three contents through the combination of theoretical learning and practical teaching based on the classroom teaching and experimental teaching of Environmental Microbiology\cite{2}: (1) Understanding the research frontier and application status of microorganisms in environmental science; (2) Understanding the principle of environmental microorganisms and the implementation and control methods; (3) Improve students' ability to analyze and solve practical problems. Improper setting of practical teaching will have a greatly negative affect on students' learning and promote undergraduate talents to meet the needs of environmental science research and environmental protection in the new times to plays a vital role in improving students' practical ability\cite{3-5}.

Scientific literacy can be defined as the understanding of scientific concepts and processes, as well as the establishment of scientific thinking\cite{6}. Understanding the thinking and methodology of scientific process is an important goal in the cultivation of undergraduate students, especially in recent years\cite{7, 8}. With the development of environmental disciplines, the research related to environmental microorganisms is increasing day by day. More than 40,000 articles related to environmental microorganisms have been published every year (Fig. 1A), while the number of articles related to environmental microorganism that can be retrieved on Web of Science has reached nearly 200,000 annually. The data show that in the field of environment, the related research of microbiology has been widely concerned in recent years and has become an important part of the field of environmental science. This tendency endows new educational objectives of undergraduate students major in Environmental Science and engineering, namely, the familiar with related scientific researches and the improvement of scientific literacy\cite{9-11}.

However, due to the limitation of students' knowledge reserve and teaching form, it is difficult for students to establish and apply scientific research thinking in the classroom of theoretical teaching. Due to the limitation of experimental site and teaching arrangement, the main purpose of practical teaching is to cultivate students' hands-on ability and experimental skills\cite{12}. As a follow-up teaching process of theoretical teaching and experimental teaching, practical teaching has the characteristics of flexible teaching time, diversified arrangements, and more tutors. Therefore, it is the most suitable teaching link to help undergraduates understand the frontiers of the subject and cultivate scientific research thinking.

In order to adapt to the new requirements of undergraduate training, teaching group of Miami College implemented the reform on EMP around the traditional microbial industries, the environmental microbiology frontiers, and the simulative scientific project. A questionnaire for this course was also used for collection of students’ evaluations and suggestions. The result showed that students had learned a lot in this EMP and their scientific literacy was really improved. The article was also attempted to give reference of settings on practical-like curriculum in the education of undergraduates.

![Fig.1 The number of published articles related to environmental microorganisms. The key words were selected as environment*, and microorganisms, or microbiology, or bacteria, or fungi, or algae, or viruses etc. The data of Fig. 1A is from CnKI, and the data of Fig. 1B is from Web of Science.](image-url)
2. Methods and materials

Participants and procedure
This curriculum reform was practiced in Henan University, Miami College in the years 2019 to 2020. Undergraduate students major in environmental science will take this EMP in their third year of college. The whole EMP lasted two weeks and took 3 credits. The aims of this EMP reform including three aspects, namely (1) be familiar with the environmental microbiology industries; (2) expand the knowledge of the scientific frontiers of environmental microbiology; (3) improve the scientific literacy of undergraduate students major in environmental science.

Miami College of Henan University is established by the cooperation of Henan University in China and University of Miami in America. The college aims to culture senior engineering and technical personnel according to the standard of international abet. Therefore, combing the advantages of these two university, Miami College continuously improving the learning environment, recruiting outstanding teachers from the whole world, and more importantly, rebuilding education teaching concepts by optimizing the teaching process and innovating the teaching methodology.

By taking a full account of the development of society, the discipline advantages of Henan University and University of Miami, and the teachers’ academic expertise, environmental microbiology was selected as one of the major teaching directions of undergraduates of environmental science in Miami College.

The reformed EMP includes 5 aspects, namely the visiting traditional microbial industry, stimulating traditional industry process in laboratory scale, academic lecture for environmental microbiology frontiers, stimulation of environmental microbiology scientific projects, and teaching and practice of article writing. The details procedure of these aspects were shown in Table 1.

| No. | Practice Description | Description |
|-----|----------------------|-------------|
| 1   | Visit of Microbial Fertilizer Stacking Process | Organize students to visit the production process in Kaifeng Microbial Fertilizer Plant located in the east suburb of Kaifeng city, and invite the factory engineers to explain the process and details of composting process. |
| 2   | Yogurt Fermentation | Organize students to ferment yogurt by themselves in the laboratory (the instructor is responsible for purchasing the bacteria, pure milk, etc.) |
| 3   | Lecture on the Frontiers of Micro-ecology | Invite well-known professors in the university to give lectures on the frontiers of science and technology in the field of micro-ecology. |
| 4   | Lecture on the Frontier of Environmental Microbiology | Invite professors from University of Miami to give lectures on the frontiers of environmental microbiology |
| 5   | Investigation on Water Micro-ecological in Kaifeng City | The students were organized to take charge of different water areas, investigate the environmental factors (N, P, COD, etc.) of water bodies, and detect the community structure of microorganisms in water bodies and sediments. |
Arrange teachers to guide students to write papers and answer questions. Explain the requirements and format of paper writing in detail, help students find the evidence of paper, perform data screening and processing, and complete paper writing.

In yogurt fermentation, the *Lactobacillus* was isolated from previous study. *Lactobacillus* and 5g sugarcane were put into 5 bottles of 200mL milk. These bottles were further placed into the incubator at 30°C for 24 to 48 hours as previously described[13].

In the simulative project, indexes pH, TP, TN and COD and DNA extraction were measured according to previous study[14].

**Measurement methods**

**Measures for academic performance.** Students were divided into several groups with 5 to 7 students in each. 2 teachers were arranged as the faculty adviser and each is responsible for 3 groups. Teachers will mark each students in the related groups according to their performance in each part of the EMP on 0 to 30 scale. **Measures for scientific literacy improvement.** In the part of stimulation of environmental microbiology scientific projects, each student group was arranged for measure the water quality index and microbial community structure of one part of water body in Kaifeng. All the data will be sharing in the whole students for free and write a paper according to these data. The paper will finally be evaluated by the teaching group in Miami College. **Measure for students’ obtaining.** Each student will submit another paper about their obtaining in the practice. This paper will be written from the following aspects. (1) What do they gain after visiting the traditional microbial industry plants? (2) Their new understanding of the frontier of environmental microorganisms.

**Table 2 Items contained in the EMP satisfaction questionnaire.**

| No. | items |
|-----|-------|
| 1   | Entirely, you are satisfied with the EMP settings |
| 2   | The visiting to fertilization plant is useful for you to understand the traditional microbial industry. |
| 3   | You have learned a lot of practical details in the yogurt fermentation experiment. |
| 4   | You have obtained a lot in the "lecture on the frontiers of micro-ecology". |
| 5   | You have obtained a lot in the "lecture on the frontier technology of environmental microbiology". |
| 6   | Your faculty adviser (teacher) is responsible and you learned a lot from him/her. |
| 7   | You are well involved in the simulated scientific project. |
| 8   | Your scientific thought and methodology have been improved in this EMP. |
| 9   | You are pleased to write your own suggestions in this item. |

**Satisfaction survey.** We employed a questionnaire with 8-items for students to evaluate their satisfaction and obtaining in the EMP. Students were answered on a 7-point Likert scale ranging from 1 (not at all true of me) to 7 (very true of me)[15]. The 8 items contained in questionnaire is shown in Table 2.

3. **Result and discussion**

**Teaching Reform Method of Environmental Microbiology Practice**

A successful setting of EMP should not only meet the traditional subject requirements, but also contain
new connotations, which mainly includes the following three aspects. (1) Current microbiological industry practice; (2) Frontier expansion of environmental microbiology; (3) Cultivation of scientific literacy. Authors focused on these three aspects and discuss the teaching settings of Environmental Microbiology Practice in conjunction with the environmental science major of Henan University's Miami College, in order to provide references for the teaching settings of Environmental Microbiology Practice in universities.

**Current microbial industry practices.** In the curriculum of EMP, the dominant purpose is helping students experience the realization of these separated experiments in a complete scientific research or practice. Therefore, the visit internship is essential. Students need to enter a more advanced and complete microbial industrial factory and laboratory for learning, to understand the production process under the guidance of professional staff. Combined with the actual situation, teaching group of Miami College of Henan University organized students majoring in environmental science to visit a microbial fertilizer pile site on the outskirts of Kaifeng in EMP.

In addition to the visit of practical production process, setting supporting experiments can deepen the cognition of students in this part. Finishing the similar practical process in laboratory and pilot scale by hands will better promote the students to transform the basic theory and experimental technology into industrial practice. Small or pilot experiments are suggested to be arranged after the internship visit. In this way, students can experience the industrial application of environmental microorganisms in a hands-on way from a practical perspective, including the yogurt fermentation, the extraction of microbial fermentation products and the red wine production.

**The Expansion of Environmental Microbiology Frontiers.** The construction of scientific research thinking is an important part of the cultivation of scientific research ability. As more and more undergraduate students choose to study further, the proportion of scientific research ability training in undergraduate teaching is increasing gradually. The grasp of the frontier knowledge of science and technology plays a role in promoting undergraduate students to further understand their own major, increase the scientific sensitivity and international vision[16, 17].

Based on the above thinking and the related curriculum, the Environmental Microbiology Teaching and Research Group of Miami School of Henan University integrates the above thinking into many courses. In the theoretical teaching of Introduction to Environmental Engineering and Environmental Microbiology, the teacher not only tells the professional knowledge, but also organizes the students to
group. The teacher enumerates the related research frontier direction, the group member carries on the choice, carries on the related literature review, the research content arrangement, reports the courseware making and the spot answer question and so on flow.

The cultivation of thinking logic in scientific research. The scientific literacy improvement is far from just mastering experimental skills, but also contains the understanding of scientific thought and methodology. According to current research reports, undergraduates majoring in science and engineering and even some postgraduates only have mastered rich experimental skills while lacking the ability of solving problem from a scientific standpoint. By setting relevant items in practice teaching, students are divided into several groups for research background investigation, experimental planning, experimental detail confirmation, data analysis and article writing. This model will greatly increase students' sense of participation and acquisition, and initially cultivate scientific research thought.

Henan University is located in Kaifeng, an ancient city known as the northern riverside town. It has West Lake Cultural Landscape of Kaifeng, Longting Lake, Baogong Lake and other lakes and interlaced waterways connecting lakes. The relationship between the microbial communities attached to water, sediment and aquatic plant roots with environmental factors is a hot topic in the study of environmental microorganisms. The detection of microbial community structure, N forms and concentration, P concentration, biochemical oxygen demand (BOD) and other indicators is the key content of undergraduate experimental teaching. Miami College of Henan University sets up "Investigation on the main Water Quality indexes and Microbial community of Kaifeng city" as the final research project in the teaching of EMP. Students were divided into different groups and were arranged for the investigation of different lakes and rivers. The sampling points and data obtained by some students are shown in Fig. 2.

Evaluation Methods of EMP

More and more policy puts forward that education must be given priority, education reform should be deepened, and education modernization should be accelerated\cite{18-20}. The core of teaching reform is to break through the traditional teaching mode and focus on cultivating students' innovative ability and problem-solving ability. The assessment method consists of two forms: process assessment and course essay. Among them, the proportion of process evaluation is 30%, mainly including the participation and activeness of students in visits to internships, frontier lectures and project completion. After the end of "Environmental Microbiology Practice", each student must submit two course papers. One is a practical paper and the other is a project essay. Through this assessment mode, a comprehensive assessment of students' active participation in practice, gains and abilities can be achieved.

The learning effect of EMP

Almost all the students speak highly of the EMP. According to the questionnaire, 70 students chose the 7th level (very true for me) in the item “ Entirely, you are satisfied with the EMP settings” and only 3 students chose the 6th level in these 2 years. This phenomenon indicated that students are surely satisfied with this curriculum setting and get involved in this practice. Moreover, item 4 and 5 get the highest elevation mark in the following items (item 2 to item 8), indicating that students found that its useful to expand the frontiers of their major. Item 3 which was about the satisfaction of yogurt fermentation get the lowest mark. Combined with some students’ suggestion, the reason was predicted as the singleness of this experiment. Teaching group of Miami College intended to change this experiment to the extraction of microbial products using small scale bio-reactor in the following EMP.

After this EMP, several students published their articles in different journals with the data obtained or using the thinking and methodology they learned in EMP. According to data, about 12 articles were published\cite{21-23}. These publications indicating that the students’ scientific literacy was really improved though the learning of EMP.
4. Conclusion
Training mode in this study plays a key role in promoting the output of environmental protection talents and supporting the future environmental construction. A good talent training mode can make more undergraduate talents meet the needs of environmental scientific research and environmental protection in the new era. Moreover, it can promote the level of environmental protection reserve talents. With the development of undergraduate education trends, practical teaching not only needs to help students learn theoretical courses and experimental teaching, but also needs to help students further understand environmental microbiology engineering practices, understand the frontiers of environmental microbiology technology, and cultivate students' scientific literacy.

List of abbreviations
EMP: environmental microbiology practice;   BOD: biochemical oxygen demand
   TN: total nitrogen;   TP: total phosphorus

Conflict of Interest
Authors have no conflict of interest to declare

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