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Systematic Arrangement of Courses to Improve students' Professional Innovation Capability

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ABSTRACT
Many college students from Chinese colleges and universities and even some graduate students are good at the professional theories, but their professional practices are very limited due to a series of objective reasons, let alone their professional innovation capability. Among those reasons, the separate arrangement of professional courses and lack of following the development trend of professional frontier are the most ones. Thus, in this study, a trial on the systematic arrangement of several professional courses for improving the students' innovation capability is exhibited, which is based on the students majoring in the Material Forming & Controlling Engineering specialty. Our investigation results on the three consecutive undergraduate graduates from 2018 to 2020 demonstrated that the new systematic arrangement is able to promote the application of the professional knowledge grasped by the students in the professional practices, to systematize their theories on materials preparation and characterization, and to provoke their interests in practical activities. Thus, almost all the students followed the new arrangement showed a fine professional innovation capability when they finished their graduation projects. The reported strategies here may be popularized to many other specialties for effectively improving the students' professional innovation capability.
Keywords*: Higher education, innovation capability, professional courses, college students, graduate students, systematic arrangement*

1. INTRODUCTION

In some universities and colleges of China, undergraduate students, and also some graduate students, have a wide variety of sources and routes about their theoretical learning. However, the sources for them to systematically expand professional experiments and practices are very limited, which has a poor influence on their professional innovation capability. Taking University of Shanghai for Science and Technology (USST) and its Material Forming & Controlling Engineering (MFCE) specialty as examples, the reasons can be concluded as follows with the professional training objectives of MFCE as a reference.

Shown in Figure 1 is a diagram about the personnel training requirements in USST. The university is trying its best to provide first-class engineering education to all the students including college and graduate students. Thus, three aspects are emphasized now and then that "Engineering", "Innovation", and "Internationalization" should be always imparted to them for training and learning.

However, how to implement it effectively is always a giant challenge to the MFCE specialty and its teachers. At USST and also many other Chinese universities, there is a common negative phenomenon that makes things run in opposite directions. On one hand, there are some unreasonable arrangements for teaching the professional courses to the students, such as 1) too many theoretical lessons but few professional practice courses, 2) the theoretical lessons and the practical courses are often separate from each other, lacking a way to combine them together to foster the students' capability of linking theories with practices, and 3) the lessons about the development trend of the professional frontier are too small or even none, which make the students dull to the new things happening in their specialties.

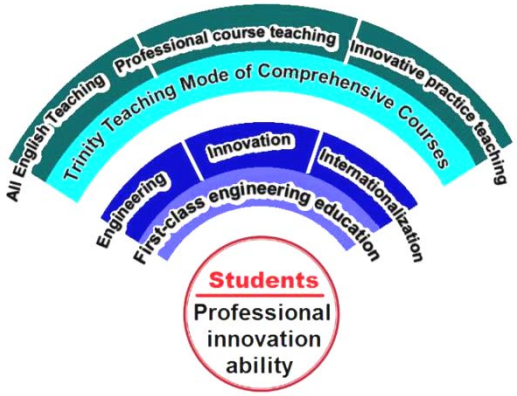

Figure 1. The professional innovation ability of students is very important for fostering professional talents in colleges and universities.

On the other hand, some outstanding scientific researchers do very well in their professional researches, but they have

no opportunities or even they are not willing to spend time and energy on undergraduate teaching, on imparting their most recent investigated results to the students for provoking their professional interests. Indeed, traditional methods of teaching are popular among teachers, and some of them have repeatedly proven proficient at the same, but unfortunately, most among them do not follow the professional frontier and development trends very well. Thus, the knowledge imparted by them is a little old, and with the growing resources available among the students, they are capable enough to acquire themselves and self-learn.

Based on the above-mentioned knowledge, here, a new trinity teaching mode of "professional basic courses/innovative practice of college students/all English Teaching" is put forward to resolve the above-mentioned issues, to implement the first-class engineering education for exporting professional talents of MFCE to the society.

2. THE IMPROVEMENT OF STUDENTS' PROFESSIONAL INNOVATION CAPABILITY SHOULD BE A PROGRESSIVE PROCESS

The final objective of education is to foster talents that can serve the development of our modern society, and improve people's life. To fulfill this objective, the students must grasp some professional skills, particularly the innovation ability during their professional carriers. However, it is not an easy task to endow them with a creative perspective and enable them with valuable knowledge of innovation. Shown in Figure 2, the top star is the innovation ability, which needs to be shaped by systematic training.

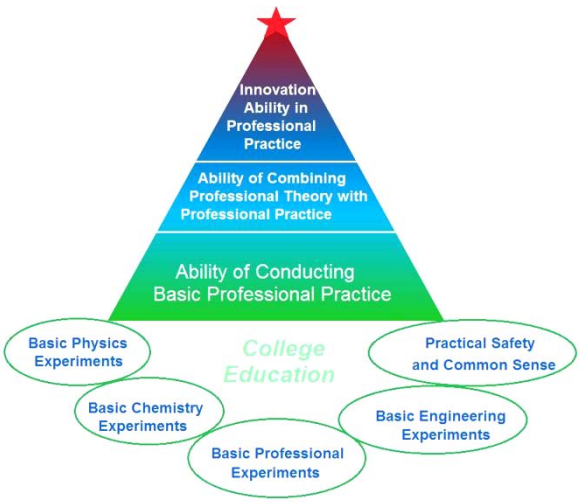

Figure 2. The innovation ability in professional practice needs a systematic and progressive process, from all types of basic educations and experiments to systematic professional practices and finally to the innovation capability training.

First of all, they need to know how to combine the professional theories they have grasped with the professional practices, which the teachers arrange for them. Only after repetitive training, it may be possible for them to carry out new practices with the guidance of professional theories. Meanwhile, to implement the novel method, they certainly need to grasp how to conduct basic professional practices, particularly those classic professional practices. For example, for a college student or graduate student that major in the MFCE specialty, the classic practices about characterizations of nanomaterials should be familiar. These characterization methods include scanning electron microscopy, transmission electron microscope, X-ray diffraction, Fourier transform infrared, and so on [1-3].

Accordingly, the above-mentioned traditional practices should be given in the preceding two years of the 4-year college life. For MFCE specialty, the basic physical experiments, chemistry experiments, engineering experiments, including safety practices and sound judgment ability should all be laid out and arranged for them. However, techniques to effectively arrange them and to make a deep impression on the students' needs to be investigated in detail. A new trinity teaching mode of "professional basic courses / innovative practice of college students / all English Teaching" is able to show a fine example for reference.

3. THE IMPROVEMENT OF STUDENTS' PROFESSIONAL INNOVATION CAPABILITY SHOULD BE A SYSTEMATIC PROCESS

Taking the professional courses of the students majoring in MFCE as an example, the new trinity teaching mode of "professional basic courses / innovative practice of college students / all English Teaching" can be utilized to explain how to improve the students' innovation capabilities in a systematic and progressive manner. Shown in Figure 3 is a schematic drawing of systematization and orderliness for course arrangement.

The inner logic for the reasonable arrangement of the professional courses is to narrow down the mainstream of social production about functional materials, i.e. the preparation, characterization and final application of a commercial product. Thus, the courses for material preparation can be arranged first, which may include courses such as "preparation and potential business opportunities of nanofibers", "preparation and application of nanomaterials", "Micro/nano forming technology and equipment", and "electrohydrodynamic atomization technology", and so on. Next, the characterization methods to characterize the prepared materials such as their morphology, inner structures, the physical status of their components, and their functional performances can be taught in the subsequent step. Meanwhile, the potential applications of those materials can be shown to the students for them to deepen their senses about material

preparation and characterization. Certainly, other modern techniques can also be integrated into the teaching system, such as the simulation design and computer simulation.
Only after the systematic comprehension of the above-mentioned knowledge, the students should be allowed to take part in the innovation and practice training with tangible results. After a certain amount of training, the final graduation project should not be a tedious challenge to them. Thus, it is clear that the trinity teaching mode of comprehensive course arrangement is to provide professional education systematically and progressively, aimed at the key ability of the professional students--professional innovation capability.

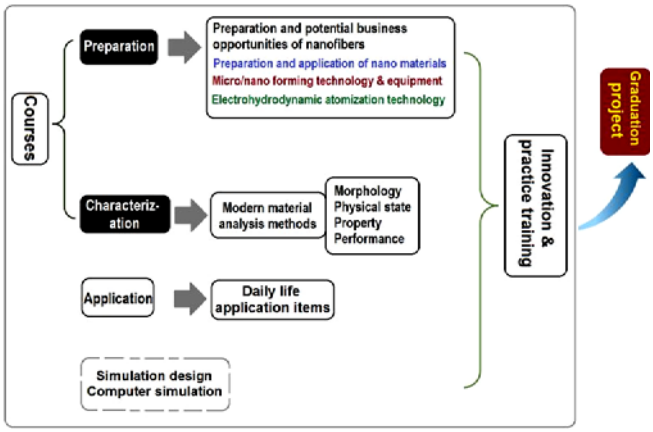

Figure 3. In the theoretical course arrangement, the courses about professional theories should form a system with each other, the practical courses and also innovation and practice training, and even the graduation project.

4. THE SCHEDULE SHOULD BE ARRANGED STEP BY STEP FROM FRESHMAN TO SENIOR YEARS

To make the innovation education of professional practice more efficacious and fruitful, a reasonable schedule for the arrangement of different courses must be formulated. There are four years for the students to spend in their college lives. Often the first year, i.e. the freshman period, the main courses are basic courses such as advanced mathematics, advanced physics and basic English (Figure 4). In this year, it is better to give one course for the general introduction of MFCE specialty to let them know the fundamental concepts.
Later, from sophomore to junior and senior years, the students should be gradually familiar with the theories and practices about material preparation, characterization and application. And the practice and innovative training projects should be inserted into their routine courses to foster their capability of linking theories with single experiments and also a whole process for developing functional materials (Figure 4). It is also in the late three years, the college English should be focused more and more time needs to be spent on professional and academic English, particularly about the scientific terms, concepts, methods and ideas. This should also be a crucial part of fulfilling the trinity teaching mode of "professional basic courses/innovative practice of college students/all English Teaching".

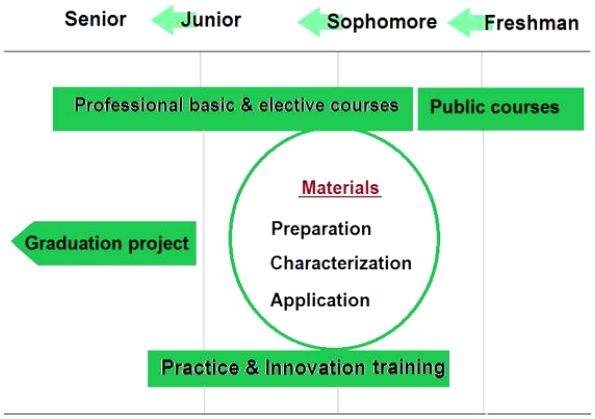

Figure 4. A schedule should be arranged step by step from freshman to senior years.

5. THE FINAL INTEGRATION AND BREAKTHROUGH IN THE COLLEGE PRACTICE AND INNOVATION TRAINING PROJECT, AND ALSO THE GRADUATION PROJECT

After a systematic arrangement of course studies for improving the students' professional innovation capability, it should be the time point for integrating them into a practical and innovative project. Furthermore, this project can also be the final graduation project. Although the project is often simple, On the one hand, it should be a petite self-sufficient apartment.
On the other hand, the topics about the projects should be about the frontier of the professional specialty. With MFCE specialty as an example, the advanced techniques for material forming and micro-forming include electrospinning, electrospraying, three-dimensional printing, molecular self-assembly, and so on. Thus, these methods should be exhibited to the students by their instructors. The physical, chemical and engineering experiments previously in the second and third years can be integrated now for systematic improvement, and it is anticipated to have a breakthrough about their capability, and professional knowledge. Some outstanding scientific researchers have found their places to do well in imparting their most recent investigated results to the students for promoting the students' professional interests and fostering new talents. Meanwhile, it is convenient for them to give the lessons in English because the students have already grasped some new concepts about professional content in English.

Shown in Table 1 are three examples of practice and innovation training for the students who graduated in 2019. All the students who had taken part in these projects have achieved a final first-rate evaluation on their graduation project. These projects have a common feature; they investigate the applications of advanced techniques in routine lives. This kind of content is significant for promoting the students' interests in beginning their professional lives.

Table 1. Practice and innovation training projects

Title	Host	Participants	Brief introduction of the project
An antibacterial and moisture-proof electrospun food preservative film	Student 1	Student 2; Student 3; …	The project developed an eccentric spin head for creating Janus fibers, which is composed of hydrophilic polymer and active ingredients. One of the two sides contained Ag NPs in the hydrophobic PCL, and the other side had ferulic acid in the insoluble EC matrix. The two sides act synergistically to endow the fibers an antibacterial and moisture-proof functional performance.
Application of detachable spin head for preparing tri-layer core-shell nanofibers	Student 1	Student 2; Student 3; …	The training project developed a tri-layer coaxial spin head, which was detachable for easy implementation. Nano drug delivery systems with a core-shell inner structure were successfully fabricated for providing the desired drug sustained-release profiles. The project has the characteristics of interdisciplinary innovations and stands in the international frontier. The spinning head invented in the project is easy to disassemble, easy to adjust and control, and can save energy for efficiently and stably production.
An electrospray micro-spheres for manipulating the sustained release of fertilizers	Student 1	Student 2; Student 3; …	The project developed an electrospraying method. Tri-layer concentric spraying head was exploited to create the core-shell micro-spheres. These particles contained fertilizers within the core section. Whereas, the sheath section can manipulate the sustained release of the loaded fertilizers through the material texture, the thickness of the sheath section, and the particles' sizes. The project has good innovation and engineering practicality, which can play a training role in the development of students' innovation capability and professional practical skills.

Project 1, i.e. "An antibacterial and moisture-proof electrospun food preservative film" is about an advanced side-by-side electrospinning process, in which an eccentric spinneret was developed for creating Janus fibers [4-7]. The prepared fibers consist of a hydrophilic polymer and active ingredient on one side, and silver nanoparticles and hydrophobic polymer on the other side. The two sides act synergistically to endow the fibers an antibacterial and moisture-proof functional performance. The project students were so interested in these contents that they went on pursuing their Ph.D. degree in this direction.

Similarly, Project 2 is about another type of advanced technique, i.e. the tri-axial electrospinning [8-10] and modified tri-axial electrospinning [11-14]. These techniques are very facile for creating double-layer or tri-layer core-shell nanofibers. The students have tried their best to develop a detachable tri-layer concentric spinneret for easy implementation. Nano drug delivery systems with a core-shell inner structure were successfully fabricated for providing the designed sustained-release profiles of the loaded drugs. Project 3 is a similar technique of electrospinning, i.e. electrospraying [15-19]—an electrospray micro-spheres for manipulating the sustained release of fertilizers. The tri-layer concentric spraying head was exploited to create the core-shell microspheres. These particles contained fertilizers within the core section. Whereas, the sheath section can manipulate the sustained release of the loaded fertilizers through the material texture, the thickness of the sheath section, and the particles' sizes.

6. CONCLUSIONS

A new trinity teaching mode of "professional basic courses/innovative practice of college students/all English Teaching" is put forward here, which is useful for implementing first-class engineering education. This mode provides a systematic arrangement of courses to improve students' professional innovation capability and meanwhile allowing the outstanding scientific researchers to do well in imparting their most recent investigated results to the students for provoking their professional interests. The improvement of students' professional innovation capability should be a progressive and systematic process. And the schedule should be arranged step by step from freshman to senior years. The final integration and breakthrough in the college practice and innovation training project and also the graduation project need the instructions from the researchers familiar with the state-of-art development and frontier of the specialty. Although in this study, the example provided is about the MFCE specialty in USST, the concepts can be exploited in many other universities and their specialties.

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