Digital Resources Construction and Education Research for the Course of Material Research and Testing Methods

De Fang [1, 2, a], Xu Gao [2, b], Han Zhou [1, c *], Ziqi Gu [2, d], Shiyang Li [2, e], Caihong Lv [3, 4, f *], and Hailing Ao [2, g]

[1] Center for Materials Research and Analysis, Wuhan University of Technology, PR China;

[2] School of Materials Science and Engineering, Wuhan University of Technology, PR China;

[3] School of Printing & Packaging, Wuhan University, PR China;

[4] Jun An Forensic Center of Hubei, PR China.

[a] fangde0914@whut.edu.cn, [b] gaoxu@whut.edu.cn, [c] zhouhan2021@whut.edu.cn, [d] guziqi@whut.edu.cn, [e] lishiyang12@whut.edu.cn, [f] lvchwhu@163.com, [g] aohailing@whut.edu.cn

Abstract. The course of Materials Research and Testing Methods aims to help students master the skills of testing and analyzing the composition, structure, property and performance of materials. To improve the teaching quality of this course and help the students understand well about the content, we introduced the distinctive teaching methods such as applying case teaching, developing virtual simulation software and database of cutting-edge instruments, carrying out instrument training, building platform of instrument popularization and national first-class course, guiding research projects and scientific competitions. Therefore, the course has its own distinctive materials that are collected to build the digital resources. How the teaching quality of this course improved by these methods will also be discussed. Furthermore, the construction of the digital resources can help students realize the new learning mode of learning at any time, flexible learning and long-term learning, broadening the channels and ways for students to study the course.

Keywords: Resources Construction; Education Research; Testing Methods; Practice; Creativity.

1. Introduction

As a national key university directly under the Ministry of Education, Wuhan University of Technology is one of the first batch of universities included in the national "211 Project" and "double first-class" construction. It is a university jointly built by the Ministry of Education, the Ministry of Transport and other ministries. Wuhan University of Technology is originated from the Hubei Craft School, which was established in 1898. The School of Materials Science and Engineering of Wuhan University of Technology is one of the important bases for talent training and scientific research of materials science and engineering in China. Founded in 1958, the discipline of Materials Science and Engineering in Wuhan University of Technology was listed as one of the first national key disciplines in 1988, one of the key construction disciplines of the national "Project 211" in 1996, one of the first national key disciplines in 2007, and one of the first national "double first-class" construction disciplines and national defense characteristic disciplines in 2016. This discipline has been Ranked A+ in the fourth round of national discipline assessment and entered the top 1‰ of the world ESI discipline ranking. It includes the State Key Laboratory of Advanced Technology for Materials Synthesis and Processing, the State Key Laboratory of Silicate Materials for Architectures, the Center of Materials Research and Analysis with the certification of China Inspection Body and Laboratory Mandatory Approval (CMA) and other national scientific research units. Relying on the first-level national key discipline of "Materials Science and Engineering", the School of MSE has more than 2910 undergraduates and 2420 postgraduates. It is a high-level talent training base of materials science with distinctive industry characteristics in China.

Wuhan University of Technology is the first university in China to set up the course of Materials Research and Testing Methods for undergraduates, and the teaching team from the Center of Materials Research and Analysis has been undertaking this course. The course of Materials

Research and Testing Methods has been offered for more than 30 years, and is one of the three core courses of seven undergraduate majors in the School of Materials Science and Engineering (inorganic non-metallic materials engineering, materials science and engineering, polymer materials and engineering, composite materials and engineering, materials physics, materials chemistry, and new energy materials and devices).

In 2020, the course was rated as a national first-class online and offline hybrid undergraduate course by the Ministry of Education. In addition to the common testing methods, such as X-Ray Diffraction analysis, electron microanalysis, thermal analysis, vibrational spectrum analysis, photoelectron spectroscopy, X-ray fluorescence spectrum analysis, plasma emission spectrum analysis, atomic absorption spectrum analysis, it also includes Auger electron spectroscopy, nuclear magnetic (paramagnetic) resonance spectroscopy, mass spectrometry, ultraviolet and visible absorption and emission spectrum analysis and chromatographic analysis, etc [1,2]. As society's requirements for students' abilities are constantly changing and teaching methods are constantly being updated, so more and more attentions are paid on the reform and development of the course.

2. Course Characteristics and Development

The course of Materials Research and Testing Methods primarily aims to enhance students' ability in utilizing state-of-art testing instruments and methodologies for materials research and analysis. It provides a solid foundation for enhancing students' competence in material development, research, and innovation. The goals of this course include three specific aspects: Firstly, to help the students acquire a comprehensive understanding of the fundamental knowledge related to material preparation and processing, material structure analysis and performance testing, product quality control and application. Secondly, to develop proficiency in testing and analyzing methods selection for structure and performance testing of materials and also the skills of operating cutting-edge testing instruments as well as the awareness of environment and safety protection during the operation. Lastly but not least is to cultivate an innovation attitude with basic innovative methodologies for materials design and analysis. Meanwhile, the teaching content, teaching method and teaching means of the course of Material Research and Testing Methods are updated by the teachers, and how to reform and improve the teaching quality of the course are put forward in recent years [3-4].

To achieving such goals for this course, a high-quality teaching team is indispensable. The course team put great emphasis on the selection and training of the teaching members. The teachers in this team are all in charge of specific high-tech instruments and in the frontline of operation and maintenance and thus accumulate abundant experience in teaching, the knowledge of instrument and data analysis. 90% of the team members hold doctoral degrees or related senior titles. 30% of them have teaching experience for more than 25 years and 80% of them have more than 8 years of teaching experience. Through their teaching, they all demonstrate excellent teaching professionalism, extensive practical knowledge and skills in experimental instruction and instrument operation. However, because of the specialty of this course, which has strong professionalism and the complicated and boring knowledge of the testing instruments, it is difficult for students to focus and understand the content. Aiming on the objectives of this course, the teaching team has conducted years of research on various aspects of teaching reform, including the implementation of case teaching, developing virtual simulation software and database of cutting-edge instruments, carrying out instrument training, building platform of instrument popularization and national first-class course, guiding research projects and scientific competitions. Therefore, the course has its own distinctive materials that are collected to build the digital resources.

Over years of refinement and accumulation, this course has become an indispensable component contributing to the remarkable achievements made by the discipline of Materials Science and Engineering in Wuhan University of Technology. Moreover, significant improvements have been

achieved in students' fundamental knowledge understanding in materials science through this course.

3. Course Innovations and Effects

3.1 Case Teaching Implementation

By combining the advantages of materials discipline the teaching resources of the Center of Materials Research and Analysis in Wuhan University of Technology, our team explored a novel teaching reform model combining theoretical teaching and practical training. By designing and implying case teaching, this teaching reform model aims to get close to the typical test and analysis cases in scientific research, factory production and living environment. Based on this teaching reform related to case teaching, our team has completed 4 teaching projects at provincial and university level and applied the relevant research results for course teaching.

The implementation of case teaching has two obvious advantages. On the one hand, by comparing and combining the different analysis method in one case, it helps students digest the relatively independent knowledge content of each analysis method, and thus helps students build solid theoretical foundation. On the other hand, by comprehensive analysis of the practical problems in factory production, it stimulates students' creativity and interest, and thus encourages students to provide solutions for developing or improving testing methods. In the case teaching process, our team collected a series of practical problem cases involving enterprise product formulation, production process, product storage and other aspects, and encouraged students to focus on key question of how to select the proper testing methods to find and characterize the problems. Through the process of discussion and summary, students can give full play of their imagination and creativity, which greatly promoted their understanding of theoretical knowledge and applied practice [5, 6]. By combining the characterization theory with the case practice of problem solving, students can master the research and analysis methods of the chemical composition, microscopic morphology and phase structure of materials from the perspective of sensibility and rationality.

3.2 Development of High-end Precision Instrument Testing Database

The Center of Materials Research and Analysis in Wuhan University of Technology, founded in 1984, integrating teaching, scientific research and testing services, is a comprehensive analysis and testing institution that have the national CMA qualification. After the construction and development over 40 years, it has become one of the important bases to support materials, chemistry, physics, environment, biology, machinery, chemical and other related disciplines of our university. It provides high-quality testing services for universities and industrial enterprises. The center, with a group of high-level professional and technical team members, has an independent and centralized analysis and testing laboratory of more than 4,000 square meters. The total value of instruments is around 120 million RMB. Among these instruments, 27 sets of the instruments worth more than 1 million RMB, including: Double spherical correction transmission electron microscope, high-resolution transmission electron microscope, X-ray photoelectron spectrometer, field emission scanning electron microscope, electron probe X-ray micro-analyzer, X-ray diffractometer, X-ray fluorescence spectrometer, infrared/Raman spectrometer, gas phase mass spectrometer and other high-end precision scientific instruments.

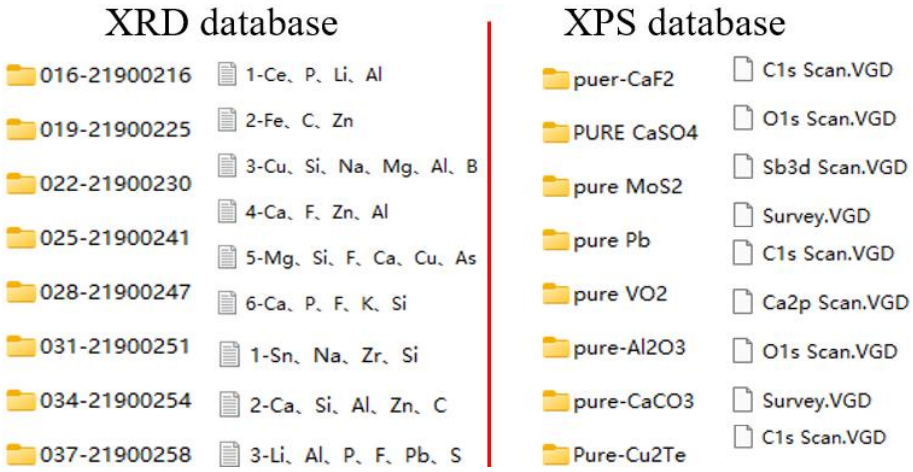

Fig. 1 The database from the high-end precision instrument tests

In order to facilitate the teaching process, our team purchased some pure samples or designed some basic samples independently, and tested their physical and chemical properties through the instruments in our center. In addition, our team has accumulated abundant working experience on the instrument platforms through the years, and collected a large amount of testing data for instrument calibration and research, and finally formed a database of various instrument (as shown in Figure 1). Based on these comprehensive information of the samples, we are able to prepare thorough test database for analysis, which becomes the carrier for us to impart the principle and application knowledge of the relevant instruments. Applying the database of the test data and analysis skills in the teaching process can promote students' understanding of analytical software and improve students' ability to analyze data, which would significantly increase students' hands-on and thinking ability.

3.3 Carrying out Large-scale Instrument Training

The Center of Materials Research and Analysis has a large number of advanced precision instruments. Students can have access to some advanced and sophisticated test instruments and methods, and instrument training has been favored by them. After entering each instrument group, the standardized instrument management system of the university's large instrument sharing platform helps students to develop a scientific, rigorous and reasonable attitude towards the use of instruments. At the same time, the teachers of the Material Research and Test Methods course team all come from the large instrument and equipment sharing platform, and can systematically explain each test method from the aspects of instrument principle, construction, testing and analysis, and can also explain the use of skills and methods that are not included in the related book. In addition, since our teaching team has been exposed to the information related to the instrument, they can also share the latest development of the instruments with students, and promote the students to build a solid foundation for research and work [7, 8].

The original assessment methods of the course were mainly through attendance, report and examination paper, which were difficult to effectively evaluate the students' ability of practical operation. This course will leverage advanced management experience in material research and testing of large instrument test platforms, requiring students to pass at least one instrument operation assessment and obtain a large-scale instrument training certificate. This requirement can not only promote the students' practical ability but also increase the enterprise's recognition of students' comprehensive ability. Furthermore, the related training videos can form the database of the instrument operations to prompt students to avoid some common mistakes and learn key operations again.

3.4 Developing Virtual Simulation Software Building a Large-scale Instrument Science Popularization Platform

Based on the operation experience of large instruments and equipment in the Center of Material Research and Analysis of Wuhan University of Technology, our team has actively involved in the development of the virtual simulation software for large-scale instruments (as shown in Figure 2).

The instrument virtual simulation software is usually accessible on the public platform online and students can learn whenever and wherever they need, regardless of geographical and time constraints. Different from the compulsory teaching methods of traditional education, students can choose the learning content and time slot of large-scale instrument virtual simulation software according to their own interests, needs and time arrangements. Moreover, there are some complex or high-risk experimental operations that are difficult for students to carry out when considering operating the precise instruments. Such large instrument virtual simulation software eliminates the risk factors that exist during the instrument operation. Students can experiment and operate in a safe environment, which could avoid the possible injuries and losses, and thus improve the safety and controllability of learning. At the same time, students can repeatedly carry out experiments and operations, consolidate and deepen the understanding of knowledge, thus improving the teaching quality [9, 10].

Fig. 2 The virtual simulation software developed for large instruments

3.5 Building a Large-scale Instrument Science Popularization Platform

The Center of Materials Research and Analysis of Wuhan University of Technology has witnessed the development of material characterization technology and the progress of materials science. Due to the relatively long service life, many instruments purchased before has been retired and scrapped, but some of their core components or even the whole components are still intact.

For these abandoned instruments, the team relied on the strength of the Materials Research and Testing Center to conduct equipment dissection and use such instruments as teaching aids and teaching platforms. At present, core components of decommissioned XRD, TEM, EPMA, XPS and other instruments are displayed in the center (as shown in Figure 3). With the help of these anatomical instruments, our team could introduce the function and working principle of each part in detail. The related core component and its mechanical movement can be collected by pictures and videos to form the database of the machine construction. This would greatly improve students' understanding of instruments, rather than just obtaining knowledge through books or courses in class. At the same time, these displayed instruments can convey the history of science and culture to students, and let students feel the charm of science and technology and the mystery of the material world, thus increasing students' enthusiasm for learning this course.

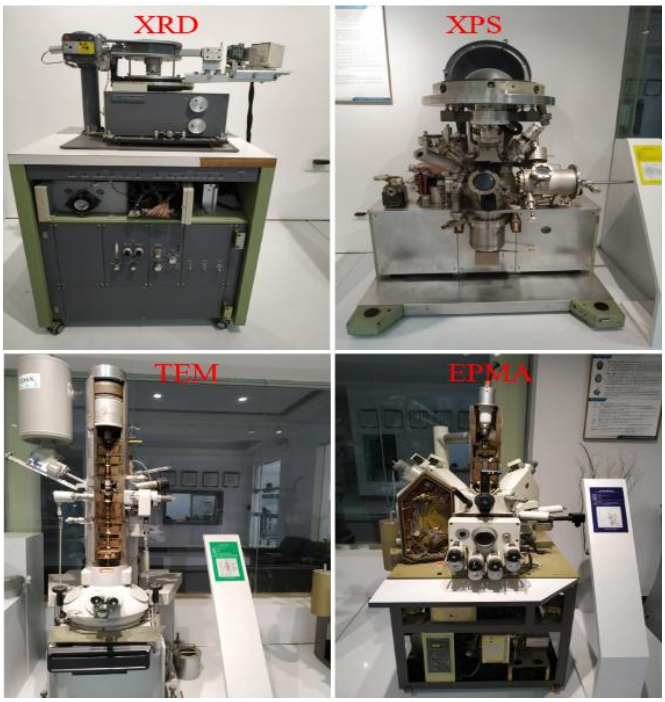

Fig. 3 Dissected large-scale instruments exhibited through science popularization platform

3.6 Building National First-class Curriculum

The team carefully designed the course system of online and offline mixed teaching mode, using Chinese university MOOC open online courses as the carrier to conduct personalized online learning course and provide all-around and three-dimensional support for offline classroom teaching. Through student-centered heuristic, discussion-based, and goal-motivated teaching, students could thoroughly understand the importance of material characterization in scientific research and industry production.

This course has been rated as the excellent course and the excellent online opening course of Wuhan University of Technology, the first-class online course of Hubei Province and the national first-class online and offline mixed undergraduate course (national "Gold Course"). The "Gold Course" attracts more and more students due to its flexibility, convenience, rich resources, personalized teaching and interaction. In the past few years, the teaching impact of this course has gradually emerged and the production-learning linkage became smooth. Moreover, the quality of personnel training through the course has steadily increased, which has been confirmed by the School of Materials Science and Engineering and the International Demonstration School of Materials Science and Engineering of Wuhan University of Technology and other peer universities as well as the society.

3.7 Directing Research Projects and Scientific Competitions

Research projects and scientific and technological competitions are very important for cultivating college students' professional basic ability and scientific research innovation ability. They can not only guide students to apply professional technical knowledge to practice, but also exercise students' scientific research innovation ability and cultivate students' teamwork ability. Research projects and scientific and technological competitions are often participated by students spontaneously, which can mobilize students' enthusiasm and initiative in learning professional and technical knowledge. Students that obtain the research projects and research awards can achieve the opportunities for advanced study, so they are keen on participating the research projects and scientific and technological competitions. In order to fully apply the theoretical knowledge of materials research and testing methods to practice, teachers in our team are encouraged to participate in guiding research projects and scientific and technological competitions. The teachers

in our team has actively created conditions to encourage students to participate in the proper research projects and science and technology competitions at college, university, provincial and ministerial level. This could improve students' material testing ability. By involving in these projects and competitions, many students have won relevant competition awards and scientific research projects, which also reflected the students' solid basic knowledge and application ability of material testing technology [11]. The related database of the research projects and scientific competitions can be built to increase the course engagement for students, since they can get relevant information of the research projects and scientific competitions.

4. Summary

The digital course resources of digital case database, database of cutting-edge instruments, instrument training video material, platform of instrument popularization, national first-class course and research projects and scientific competitions database are built and applied for the teaching. Through digital course resources, students could not only learn the basic characterization methods of material microstructure analysis, phase analysis, physical property analysis and chemical composition analysis, but also master the basic principles, experimental techniques and analytical methods of modern testing equipment. A solid theoretical foundation and systematic professional knowledge of material testing technology could be built through the digital resources construction, and the students can be competent for higher level teaching, scientific researching, engineering and science and technology management in the field of material testing technology.

Acknowledgements

This work was financially supported by the Cooperative Education Program of Ministry of Education (230804382134739) and the 2023 program of graduate education and teaching reform at Wuhan University of Technology (construction and research of the teaching case base for the course named contemporary analytical techniques for material characterization).

References

[1] Yu Yang, Wang Tao, Fu Luxiang, Kang Hailan, Li Peng, Zhang Hui. Exploration and practice on the teaching of materials research methods and testing technology. Modern Chemical Research, 2022, (3): 123-125.

[2] Li Hao. Discussion on teaching reform of material research and testing methods. China Modern Educational Equipment, 2015, (3): 71-73.

[3] Yang Xinya. Teaching reform practice of material research and testing methods. Journal of Technology College Education, 2006, 25: 113-114.

[4] Yao Xiaxi, Hu Xiuli, Wang Xuhong, Liu Longfei. Teaching practice and exploration on the course of modern materials analysis techniques and experiments at the major of functional materials. Modern Chemical Research, 2023, (1): 158-160.

[5] Kevin M Bonney. Case study teaching method improves student performance and perceptions of learning gains. Journal of Microbiology and Biology Education, 2015, 16: 21-28.

[6] Susan F McLean. Case-based learning and its application in medical and health-care fields: A review of worldwide literature. Journal of Medical Education and Curricular Development, 2016, 3: 39-49.

[7] Song Xinghui, Liu Shuangshuang, Huang Yingying, Li Yanwei, Wang Jiajia, Guo Chun, Xing Yueting. Study on talent training model and path of large-scale instrument sharing platform in colleges and universities: Based on practice and exploration of public technology platform of Medical School of Zhejiang University. Experimental Technology and Management, 2022, 39: 232-235.

[8] Niu Weihua, Sternberg Robert. Contemporary studies on the concept of creativity: The east and the west. Journal of Creative Behavior, 2002, 36: 269-288.

[9] Wang Yangping, Dang Jianwu, Yong Jiu, Wang Wenrun, Yue Biao, Jin Fangrui. Research of virtual simulation experiment course resource intelligent information system construction. 2022 IEEE 2nd International Conference on Power, Electronics and Computer Applications (ICPECA), Shenyang, China, 2022, 969-973.

[10] Yang Molan. To What extent virtual simulation technology can aid education. 2021 3rd International Workshop on Artificial Intelligence and Education (WAIE), Xi'an, China, 2021, 22-26.

[11] Zhang Rui, Han Huijian. Driven by subject competitions to cultivate college students' innovation and entrepreneurship ability. 2021 11th International Conference on Information Technology in Medicine and Education (ITME), Wuyishan, Fujian, China, 2021, 480-484.