SPECIAL REPORT

Establishing Standardized Biomedical Laboratory Technician Education for the Development of Biotechnology Research in China

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Abstract Chinese scientists have been actively engaged in biotechnology research since the mid-20th century. However, biotechnology education, especially biomedical laboratory technology education, is relatively scarce in China. More and more cutting-edge equipment and techniques have been introduced into biomedical laboratories in China, but there is a lack of high-quality technicians to apply these advancements to scientific research. In addition, the traditional education and apprenticeship systems have been demonstrated little progress. To address this gap, West China Hospital of Sichuan University established a 2-year educational program for laboratory technology in 2006 based on the residency training program. The project integrates scientific methods into the research laboratory technician training in relevant disciplines, and has developed a systematic, scientific, and effective standardized training system to cultivate high-level and stable experimental technician team for the need of advanced laboratories, which has been demonstrated greatly improve the efficiency of biomedical researchers and laboratory facilities. In this article, we introduce the practical experience in establishment and development of a standardized training system for biomedical laboratory technicians to ensure the sustainable development of medical researches.

BIOMEDICAL laboratories are constantly subject to advances in medicine, technology, and society. Currently, research teams mainly comprise scientific researchers who propose ideas, operate experiments, and write papers,

as well as technicians who engage in analytical testing, operation/maintenance of instruments and equipment, and processing samples. Biomedical laboratory technicians have significant responsibilities and make important contributions to introducing advanced analyses and using innovative instruments. Data from Chinese Ministry of Education in 2006 showed that there were 12 408 laboratory technicians (35.5% of all university teachers).^[1] This means laboratory technicians have a

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major influence on laboratory construction and development.^[2] Over recent decades, the Chinese government has made massive investments in biomedical sciences, so there are increasing demands for biomedical laboratory technicians.^[3] Biomedical laboratory technicians who are equipped with advanced knowledge can ensure good adaption of a biomedical laboratory to the evolving needs of research quality and experimental rigor, and therefore make positive contribution to the continuous development.^[4,5]

Shortage of technicians is a challenge for most academic institutes and universities in China.^[6] The workforce of technicians is insufficient, their educational levels are relatively low, and the average age of this professional group increases. It was reported that 17.9% of technicians in China were with medium education, the majority had basic education, while about 80% of technicians with college and university education are over 40 years old.^[7] Many biomedical scientists have reported the lack of technicians as a major bottleneck restricting scientific researches in China.^[8,9] However, the role of a biomedical technician is not easy to be introduced, and in most institutes and universities, the development of medical laboratory research technical teams were not attached enough importance. This has resulted in a workforce shortage and an overall poor efficiency of experimental technical teams. The deficiency in laboratory technology education in life sciences is an important contributing factor to this shortage.

THE BIOMEDICAL TECHNICIAN TRAINING PROGRAM

To date, biomedical laboratory technology education in China has been underappreciated. In contrast, most biotechnology companies and universities in the United States have specific programs focusing on training high-quality biotechnology technicians.^[10] For example, in community colleges of the United States, there have established 2-year biotechnology certificate programs, and the US Department of Energy has provided a grant to the National Education Development Center to develop industry-wide skill standards for biosciences technicians.^[11] In Australia, core educational programs have been adapted to respond to the future need for expertise in biomedical laboratory science.^[12] Currently, there are two educational pathways for training biomedical technicians in China. One is the

apprenticeship system, where students receive hands-on instruction from a biological technician individually. In this system, teaching content varies from person to person, the personal experience of apprentices is dominant, and no standardization is available. The other is the traditional school system, where students study in vocational school (usually vocational middle school) or junior college for 3–4 years. However, the school system usually cannot offer adequate training resource because of the underdeveloped training program, shortage in financial support, and weaknesses in teaching structure.

The West China Hospital (WCH) of Sichuan University has set the developing goal to become the top hospital in China. Based on this goal, we established a standardized training program for laboratory technology in 2006, which is the first formal biomedical laboratory technology education program in China. It has the capacity to recruit 20 trainees per intake. The trainees are recruited from the best examinee based on comprehensive evaluation of their interests, motivation, comprehensive personality, problem solving ability and English ability.

A highly-qualified instructor team

Establishing an experimental technician team is systematic, and requires a professional mentor team in priority.^[13,14] Collectively, to achieve the educational goals of the program, the mentor need enough professional background and have academic and experiential qualifications. The composition and responsibilities of the mentor team are as follow:

1. Instructors (especially the frontline senior technicians or post doctors) must process knowledge, skills, and attitudes that are needed to work effectively in standard and diverse settings and be able to bring theoretical and practical teaching expertise into the training program.

2. Each instructor in team is responsible for mentoring a trainee by part-time. As instructors are laboratory staff, they have opportunities to participate in biomedical research projects of the institute, which brings them rich practical experience, and results in better integration of teaching goals with their experiences in experimental approaches.

3. The lead instructor must stay up to date on developing instructional methods, formulating teaching curriculum, management of training and evaluation.

4. There is an instructor leader for each train-

ing module who is responsible for the management of instructors (ideally every training module has five instructors), preparing and organizing experimental materials, instructing experimental operation and providing theoretical interpretation.

5. The teaching team has at least one senior professional, such as professor or equivalent.

Powerful training platform

Establishing a training platform requires a joint effort. The training platform available in WCH is housed in two public service facilities, the Research Core Facility and the Experimental Animal Center, in association with some research laboratories. The Research Core Facility comprises three laboratories: a molecular lab, a cellular lab, and a pathology and image lab. These labs are equipped with over 300 instruments and occupy a space of over 2000 square meters. Equipment available include flow cytometers (sorter and analyzers) (BD FACSAria SORP), two-photon confocal microscope (A1RMP+, Nikon), atomic force microscope (SPA400, SEIKO), small scanning electron microscope (EVO10, ZEISS), microCT/small animal imaging data analysis system (PerkinElmer, Analyze 12.0), structured light illumination/confocal/total internal reflection super-resolution microscope (N-SIM, Nikon), etc. The Experimental Animal Center is an open-source platform that is set up for researches using specific-pathogen-free mice, rats, rabbits, beagles, or rhesus monkeys. It supports developing various animal models of diseases by using transgenic, oncological, surgical, and infection methods. *In vivo* imaging technologies (X-ray, bioluminescence) are also supported by the facility. The training platform integrates multi-dimensional resources in term of technology, instrument, and physical spaces available in the hospital, and provides sufficient systematic support that meet the requirements for the training of biomedical technologies.

Standardized training curriculum

The standardized training curriculum in experimental technology covers broad specialties. The basic experimental technologies that trainees will learn include cellular biology, molecular biology, animal experimentation, pathology and image technology. Besides, in the module of the expand and deepen learning, trainees will also share new technologies and advances in biology with research staff. This module aims to cultivate trainees' initiative, collaborative and

motivated attitudes. In addition, to ensure training quality, the trainees quantity is limited to 20 trainees every year, and the group learning for skills and theory in a standard-based module is limited to five students per group.

The training program is set for 2 years, and is divided into two parts: cycle training (**Table 1**) and fixed subject training. The content of cycle training section covers the safety and compliance, rules, and policies of laboratory, the principles, operations, maintenance of laboratory equipment and instruments, and the performance rules of basic experiments according to standard operating procedures. The fixed subject training section offers trainees opportunities to engage in laboratory management and research projects with medical researchers. The management team will assign trainees to corresponding research teams according to their technical expertise. In the research teams, trainees not only participate in the research projects to exercise their skills learned, but also have an opportunity to learn the construction and management of a laboratory. Through the fixed subject training, they will have rigorous experimental thinking, skilled experimental technique, and rich experience in laboratory management. The two sections highlight the importance of different aspects, and are integrated together in program for the best teaching-learning consequence.

In order to adapt to emerging technology and equipment of the domain, expand the trainee's vision, and optimize the technical system, the training courses have specially-designed sections, namely "weakness identification" and "new technology learning and communication", to strengthen the standardized training content with novel techniques and methods. The prior one mainly provides student with self-learning literature and materials for theoretical study and simultaneous opportunities for intensive practice of specific experimental techniques; the latter is a combination of theory learning and operation focusing on the emerging technologies and guided by instructors.

Systematic and scientific evaluation system

Evaluation is an ongoing process rooted in the whole process of our training program to ensure the quality of training program through continuous assessment, evaluation, and revision as needed.^[15] Currently, the evaluation of students are based on their achievements and self-appraisal, aiming to assess the effectiveness

Table 1. The arrangement of cycle training period

Modules	Main contents	Time
Lab safety	Lab safety	2 days
01-Molecular technique	Extraction of DNA and RNA, molecular cloning, real-time PCR, western blot, expression, detection and purification of recombinant proteins from bacteria, determination of molecular weight and concentration of a chemical compound by HPLC, assessing purity of one chemical compound by LC-MS	5 weeks
02-Cellular technique	Cell line culture, primary cell culture, general staining, CCK8 for cell viability assays, cell cycle and cell apoptosis by flow cytometry	5 weeks
Expand and deepen learning-1	Cross integration of experimental techniques learned in the first two modules, expand learning of scientific research standards, academic ethics, and laboratory management	1 week
03-Pathology technique	Paraffin embedding and section, frozen section, special stains, immunofluorescence staining, immunohistochemistry, FISH	5 weeks
04-Animal experimentation technique	Anesthesia, tail vein injection, blood collection, intragastric administration, and SPF mouse administration	5 weeks
05-Image technique	Sample preparation, microscopes practice, image analysis	5 weeks
Expand and deepen learning-2	Review and integrate the experimental techniques learned in the last three modules, expand learning of laboratory safety management and equipment management.	1 week

PCR polymerase chain reaction; HPLC, high performance liquid chromatography; LC-MS, liquid chromatography-mass spectrometry; CCK8, cell counting Kit-8; FISH, fluorescence in situ hybridization; SPF, specific pathogen free.

of academic training.^[16] Our three-stage evaluation protocol involves immediate feedback, post-training tests, and post-training appraisals.

The first stage: self and mutual assessments

1) Trainee evaluation: all trainees complete a standardized evaluation form at the end of each module to evaluate their own performance and that of the instructors. Knowledge gain is the main content of self-evaluation, including how well the trainees have mastered the knowledge and skills and how satisfied to the learning content and training staff. We also collect their recommendations, which are particularly valuable for instructors, instructor leader and technical training committees to improve the course and ensure it meets the needs from trainees.

2) Instructor evaluation: upon completion of training tasks, instructors complete a questionnaire to evaluate the performance of themselves and their trainees. Instructors give assessment for each trainee in terms of experimental operation, attitude, collaborative and supportive consciousness, and reading ability of literature.

The second stage: post-training tests

Assessments of trainees' performance are carried out throughout the program. Trainees' final grade is determined by basic knowledge evaluations every 6 weeks in the cycle training section and evaluations every 3 months in the fixed subject training section

through examinations, evaluations and reports.

1) Experiment report: to evaluate trainee's attitudes and behaviors, we require each trainee to write and submit an experiment report by a scheduled date after completing each module learning. The instructors check these reports against students' academic performance and professional attitudes.

2) Examinations: to assess trainee's ability to undertake tasks in the workplace, they are independently rated by practical and theoretical examinations under careful monitor. The examinations cover quality assurance in operation and skills, biosafety consciousness, theoretical knowledge, ability to follow directions, and ability to work under stress. Periodical tests are carried out throughout the cycle training period, and there is a comprehensive examination at the last week of every module.

The third stage: post-training assessments

The assessment is primarily undertaken by the supervisors. After completing cycle training section, the management team evaluates working ability and attitude of trainees. Supervisors adjust teaching contents and methods according to knowledge levels and circumstances of individual trainees to ensure that each trainee receives the most suitable training so that their experimental skills improve continuously.

The training curriculum is adjusted annually based on the feedback from instructors and students, and

we incorporate the modification into the educational content continuously.^[17] The evaluation mechanism runs through the training and serves as the important approach for continuous development of the training program.

TRAINEE PERFORMANCE

To assess the effectiveness of the training program on trainees, we adopted the Kirkpatrick model to evaluate our training program.^[18, 19] From July 2014 to June 2019, 75 trainees (18 with master's degree, 53 with bachelor's degree, and 4 with college education) participated in our training program.

Table 2 presents the evaluation results of trainees by instructors at the first level evaluation which value four aspects: operation skill, learning attitude, collaboration and support, and literature reading. Although the interpersonal variation in operation skill is obvious, which may come from their experimental experience, it was accompanied with big discrepancies in their attitude, collaborative & service consciousness, and literature reading ability, suggesting that learning attitude may serve as the core factor for trainees to achieve the training goal, and more attentions should be directed to problems in trainee's learning attitude. Besides, we found the learning performance on operation skills, attitude, and collaborative & service consciousness had no association with students' educational background. Regarding the

examination results of the five modules (**Table 3**), the scores of practice skill were less variable than the knowledge scores; particularly, knowledge scores of the molecular technique module and the cellular technique module were more variable than that of others, which indicate a large interpersonal difference in knowledge learning.

It is worth noting that in the fixed subject training period when personalized training based on trainees' individual characteristics was carried out, there was significant score increasing in term of the operational skill with a much less interpersonal variation in trainees. This indicated that the fixed training improves trainee's operational skill level. We propose that when adopting personalization in technique training, it is highly effective and also produces significant knowledge gain and service consciousness in trainees. Upon the evaluation system, we get the feedback to understand the underlying reasons of an individual trainee's performance. This is a valuable approach for a laboratory research technician training program to make on-going correction or remediation appropriately.^[11]

RETENTION OF TRAINEES AFTER TRAINING

The WCH laboratorial technology training program aims to cultivate technicians who pursue high-quality professional career, or are about to join in advanced

Table 2. Immediate evaluation on learning performance of trainees ($n=60$)

Sections of training program	Operation skill (score/full=45)			Learning attitude (score/full=20)			Collaboration & service (score/full=20)			Literature reading (score/full=15)		
	Mean	Range	CV	mean	range	CV	Mean	Range	CV	Mean	Range	CV
Cycle training	36.3	26-34	5.4	14.5	12-19	5.4	13.2	11-18	5.5	13.5	6-15	8.2
Specialty training	41.0	39-42	1.7	17.6	16-20	2.2	15.2	15-19	2.5	13.5	12-15	4.3

CV, coefficient of variation.

Table 3. Scores of trainees in practice and theoretical exams of each module[§] ($n=60$)

Modules	Practice skills score			Knowledge score		
	Mean	Range	CV	Mean	Range	CV
Molecular technique	91	89-93	7.5	92	60-94	32.1
Cellular technique	91	80-97	11.1	82	60-93	31.3
Pathology technique	92	90-93	2.5	85	76-92	18.5
Animal experimentation technique	96	95-98	3.4	88	81-93	9.6
Image technique	92	89-94	4.2	89	75-95	21.4

[§]full score is 100.

study programs. Many talented technician trainees stay and work in our hospital's laboratories after graduation. Other trainees enter some biological companies after graduation. Since the establishment of the program in 2006, annually more than 50% trainees have stayed and worked as a technician at our hospital except in 2008 and in 2012 (**Table 4**). Therefore, developing a training program could be regarded as an investment: it builds skills and upgrades their learning potential for individual trainee; meanwhile, it produces well qualified technicians to aid the development of hospital/university.

SUMMARY

Biomedical research laboratory is one of the core department in a university or a hospital.^[20, 21] Top research laboratories require first-class researchers, advanced equipment, and highly qualified laboratory technicians.^[22,23] The shortage of technicians and their insufficient ability in grasping advanced technologies have pressurized the construction and management of a laboratory,^[15,16] which rendered the importance of a training program on laboratorial technique. This paper introduces the nation's first standardized training base — the West China Hospital Science Technician Standardized Training Program at Sichuan University. This standardized training approach is developed for the goal of culturing high quality laboratory technicians in biomedical fields. Over the past 10 years, technicians who had completed the program have distributed across the nation in over 100 laboratories. Beside pro-

viding technical support, they also take responsibility of management, training and other relevant tasks in laboratory construction. Presently, many universities have assigned their technical staff to join in our training program. After completing the training, they return back working more efficiently and carrying forward the training approach to their own work setting to develop their successive technician teams. The present training program has cultured highly qualified and reliable laboratory staff, and provided the most stable support for the sustainable development of biomedical laboratories.

Conflict of interests

None.

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Table 4. The trainees' career development of the training program in the past 12 years

Year	Total graduates	Stay in (n/%)	Leave (n/%)
2008	16	6 (37.5)	10 (62.5)
2009	6	4 (66.7)	2 (33.3)
2010	13	8 (61.5)	5 (38.5)
2011	10	5 (50.0)	5 (50.0)
2012	10	3 (30.0)	7 (70.0)
2013	7	6 (85.7)	1 (14.3)
2014	13	8 (61.5)	5 (38.5)
2015	11	7 (63.6)	4 (36.4)
2016	15	13 (86.7)	2 (13.3)
2017	20	15 (75.0)	5 (25.0)
2018	20	17 (85.0)	3 (15.0)
2019	20	15 (75.0)	5 (25.0)

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