Advances in Social Science, Education and Humanities Research, volume 232

4th International Conference on Arts, Design and Contemporary Education (ICADCE 2018)

Research and Discussion on Training Model for Makers in Colleges and Universities Under the New Normal of Education Development

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***Abstract*—Exploring a practical, feasible, and efficient training model for makes under the higher education system is an important work under the new normal of educational development. This paper focuses on the analysis of the status quo and existing problems of the current education development of makers in colleges and universities, and thus puts forward the basic conditions to support the education of makers. The ideas and solutions of maker training model mentioned in this paper are the actual teaching results based on the long-term exploration of FabLab Innovation Center of Sun Yat-sen University, which have gone through theoretical and systemic in-depth discussions, and are expected to provide reference for the maker training model of other colleges and universities.**

Keywords—maker education; innovation-driven development; interdisciplinary; Fab Lab

I. INTRODUCTION

At present, the maker education of colleges and universities are still in the development stage. Due to the constraints of venues and funds, many colleges and universities fail to create a platform for makers to exchange and share, and they have no way to start the maker education, or form a systematic teaching model, besides, there are still many problems that need to be solved for the innovation and entrepreneurship education for teachers and students in colleges and universities. Therefore, exploring a practical, feasible, and efficient maker training model under the higher education system has become an important mission for colleges and universities as the main units for the training of innovative and entrepreneurial talents.

II. STATUS QUO AND PROBLEMS OF THE MAKER EDUCATION IN COLLEGES AND UNIVERSITIES

A. Emphasis on Theory, Lack of Effective Test Standards in Practical Application

China's maker education has risen since 2012, and entered the high-speed development stage. After Li Keqiang visited Shenzhen Chaihuo Maker Space in 2014. Compared to European and American colleges and universities, China's education for makers in colleges and universities is still at an initial stage, and there is no mature efficient talent training model that can be used for reference at home. Therefore, the current education for makers in colleges and universities is in a state of "no experience, no system, no standard". Teachers in colleges and universities do not have practical experience, and they mainly focus on the introduction of general knowledge, policy, and the learning of theoretical knowledge in practical teaching process. The maker education system is not perfect, so there are relatively few opportunities for applying equipment practices, presenting innovative ideas, field trips, and physical creation. In practical teaching tests, the formalized methods such as course papers, project proposals, and PPT presentation are often used as the main basis for teaching evaluation, the way students actually apply knowledge is limited to the text, and the application effect of practice in teaching lacks effective test standards.

B. The Training Model Focuses on Single Majors, with a Low Interdisciplinary Degree

Constrained by the national conditions, undergraduate education majors in China's colleges and universities are set up in three levels: "subject category,""large classification of subjects (first-level subject)," and "major" (second-level subject). It is often carried out according to the majors of departments in maker education, and the departments in

colleges and universities individually train makers. Although colleges universities have set up separate departments and agencies that are responsible for innovation and entrepreneurship in recent years with the needs of the "mass entrepreneurship and innovation" national strategy, the comprehensive linkage and interdisciplinary teaching between disciplines and disciplines, departments and departments are still vacant, and few colleges and universities are exploring. Taking the major of economics as an example, maker teaching always focuses on business planning, financial analysis, and entrepreneurship programs; while majors in engineering category focus on conceptual innovation, structural innovation, and system innovation. The former lacks the necessary scientific and technical support, while the latter lacks commercial packaging and market analysis. Without deep interdisciplinary cooperative development, neither of them can form a complete model of maker training alone.

C. Formalization of Maker Education Contradicts with Times and Social Development

As the government proposes a series of major national development strategies such as "innovation-driven development," "Made in China 2025," and "artificial intelligence", the demand for colleges and universities to train interdisciplinary talents has risen rapidly. Maker education is one of the most important aspects in the training of interdisciplinary talents in colleges and universities, and is one of the focuses of teaching reform in colleges and universities. At present, colleges and universities still carry out maker education by setting up maker space, holding maker contests, establishing maker club, holding seminar on maker education in colleges and universities. The original intention of its establishment is good, which allows a wider range of teachers and students to participate in the research on makers' cause and the discussion of the maker spirit. However, in the long run, with the shortage of teaching resources and the scarcity of high-quality teaching resources today, it is difficult for colleges and universities to continuously carry out these activities in high quality in a long term, and the maker education often becomes a mere formality or empty talk. The contradictions between formal maker education and the social needs of the times have become increasingly prominent and reform is imminent.

D. Maker Education Following the Traditional Teaching Model

In the traditional curriculum teaching, the standard that teachers need to achieve is the "1 to 1" problem solution in directional thinking, the problems are fixed, and the teachers only need to prepare problems set in the lesson and clear answers, and the course teaching is in good condition depends on lesson preparation. The maker course is an open course that mainly teaches students how to understand materials, how to use the tools and equipment around them, and adopt appropriate methods to achieve digital manufacturing and complete their own creativity. The first important concept that the maker course puts forward to students is "not requesting me, but I request". Each student leads a different project and direction, and the related knowledge areas are even more different, which may be physics, structures, and engineering, materials science, etc., therefore, the questions raised by students will also be different, and the traditional teaching methods cannot meet the needs of maker education; according to the proposed problems, a "many-to-many" course teaching model is built, that is, what the teaching of maker course needs is not a teacher, but a group of maker teachers, to lead the teaching model, make use of the network information technology, develop independent learning platforms and build interdisciplinary creative design challenge courses.

III. BASIC CONDITIONS TO SUPPORT MAKER EDUCATION

Personal Making first derived from the Micro-Assembly Laboratory (FABLAB) established by Prof. Neil Gershenfeld of the Massachusetts Institute of Technology, which was the first Bit and Atomic Research Center in the world. Xinhua College of Sun Yat-sen University established the Maker Laboratory in 2014 (hereinafter referred to as FabLab XH for short), and started the "interdisciplinary" maker training mode, to identify the orientation in the training of innovative and entrepreneurial talents, and cultivate science and technology makers relying on student organizations and professional basic innovation. The following are all based on the long-term practice of FabLab XH. This is taken as an example to demonstrate to other colleges and universities the basic conditions to support the practice, application and development of maker education in "Fig. 1".

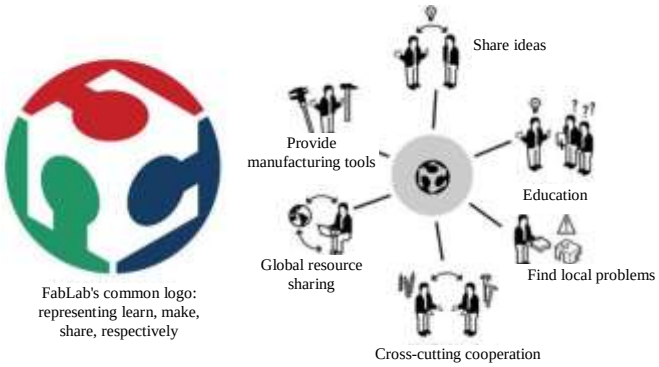

Fig. 1. Maker Development Model of MIT FabLab.

A. Hardware and Software Facilities Required for Maker Training

FabLab XH is located in Area C, 6th Floor, Gewu Building ①, Xinhua College of Sun Yat-sen University, Machong Town, Dongguan City, Guangdong Province. It covers an area of about 1000 square meters and is divided into a production area and an exchange area. There are training rooms and lecture room in the exchange area, which are used for activity exchanges, lectures, and learning of the makers; the production area is the main development area for the makers, and all the works that contain new ideas are born here.

The production area mainly includes the following digital equipment: laser cutting machine (for making two-dimensional parts for assembling three-dimensional structures), large-scale CNC milling machine (making large-scale furniture parts), cutting plotter (marking the appearance of the product, flexible

electronic circuits), desktop-grade Roland milling machine (mainly used to make mold prototypes, copper-clad circuit boards), desktop-grade 3D printer (mainly used to make product parts, practical 3D prototypes), plotter (mainly used to draw building plans, circuit layouts, mechanical drawings, computer-aided design drawings, etc.).

The interdisciplinary creative design challenge course is set up on a semester basis. The online maker knowledge sharing platform is constructed based on three aspects: stratified combination of curriculum knowledge, curriculum knowledge and basic knowledge popularization, professional knowledge consolidation and specialized training. The first is to popularize the associated knowledge and skills; the second is to consolidate specialized knowledge, set up special topics in accordance with the main direction, and raise the difficulty of training; the third is to link subjects and project-driven assistance. Through the quality evaluation system in four aspects: thinking derivation process chart, manufacturing of project prototype, project's manufacturing document, course problem record and solution plan, to train maker talents in colleges and universities, at the same time, the laboratory is equipped with 2-3 instructors that have received professional maker training (Fab Academy Certified); 5-10 laboratory assistants who understand the spirit of makers and the development of the industry, and are proficient in the safe use of laboratory machines and equipment; according to different departments and majors (students' majors include but are not limited to: financial engineering, electronic information science and technology, financial management, public administration, law, foreign languages, etc.), 40-60 maker students who are closely connected with ""mass entrepreneurship and innovation" and are interested in high technology.

B. Establishment of the Thinking Framework of Maker Training Model

1) To break the mindset, establish the awareness of "innovation,creation and entrepreneurship", combine professional knowledge and skills, and train interdisciplinary makers with "one speciality and multiple merits": Breaking the mindset formed by exam-oriented education over more than a dozen will be the primary issue to be solved in maker education curriculum. How to establish "innovation, creation and entrepreneurship" awareness is also an important aspect that should be focused on in maker education curriculum. In interdisciplinary maker education curriculum, students are introduced to understand various materials, structures, master various production methods, and make anything of any size with digital equipment. At the same time, students are fully encouraged to use their professional expertise to take their own major as a project entry point, promote the coupling of professional knowledge and expertise, and train interdisciplinary makers with "one speciality and multiple merits", deeply understood professional knowledge, and a variety of problem-solving skills. Throughout the course, Students make while learning, and learn while make, which is a "cycling" process.

2) Teachers and students share teaching resources to achieve "low input and high output": With the continuous development of maker education curriculum, the curriculum quality evaluation system will continue to improve. The problems encountered by teachers and students in the previous courses will basically cover the problems encountered by teachers and students in later courses, realizing the systemization and sharing of teaching resources. Most of the problems can be solved independently by students themselves by reading the data. This will not only greatly reduce the teacher's teaching pressure, but also help teachers to concentrate on in-depth research, explore new problems, and fully train students on abilities to study independently, teamwork, and information collection, and break through the mindset, etc. Teachers and students share teaching resources, which will fully guide the optimization of teaching resource utilization, and achieve "low input, high output."

IV. CONSTRUCTION PROGRAM FOR MAKER TRAINING MODE

A. Construction of Ecosystem for Maker Development with "Innovation-Creation-Entrepreneurship-Financing" to Realize Spherical Development

The so-called "ecosystem for maker development" refers to a system of coupled development built by various stakeholders, including but not limited to schools, teachers, students, and related cooperative companies, through mergers, alliances, and openness to expand horizontally and deepen vertically. Interdisciplinary is an important feature of the ecosystem of maker development. In this process, information flow and consciousness flow are stirred and collided in the ecosystem, just like a rotating Tai Chi in an endless succession. A good ecosystem should have the following properties: linkage, win-win nature, continuity, freedom, and evolution. Therefore, the most valuable thing that the ecosystem of the maker development has brought us is that we can examine the development of the development of entire maker education from an overall perspective, so that we can have a deep understanding of it and thus position ourselves more accurately, to adapt to this ecosystem full of vitality and crisis. Since the nature of the Internet is to integrate resources through information advantages, the cost of interdisciplinary is much lower than that of other industries, and the Internet is also the most aggressive and subversive. Therefore, the construction of maker development ecosystem with "innovation-creation-entrepreneurship-financing" based on the Internet will greatly reduce the sunk cost of maker education in colleges and universities, and improve the utilization of teaching resources.

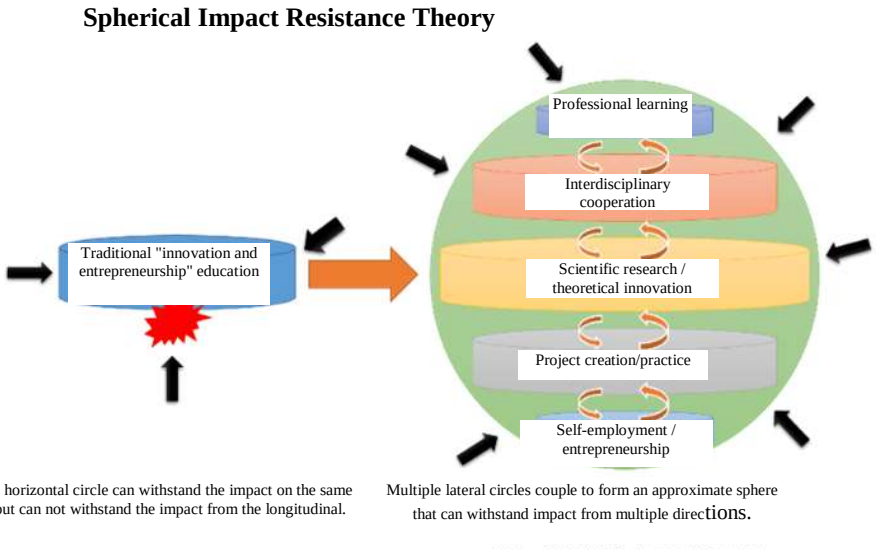

Fig. 2. "Spherical impact resistance theory" - Comprehensive development system for college students' innovation and entrepreneurship.

B. Construction of an Interdisciplinary Student Organization in the Form of "Project + Competition + Team"

Students are guided to establish research projects independently and encouraged to participate in various competitions through make curriculum teaching, including but not limited to: National College Competition on Internet of Things, Challenge Cup Competition, Internet "+", etc. To show the achievements of maker projects through various competitions, to test the actual quality of maker education, link up high-quality projects at home and abroad, promote the development of "research teams" to "startup teams and entrepreneurial teams", and arrange physical experience of makers in colleges and universities: Maker Faire, high-tech trade fair, visits to maker labs in other colleges and universities and well-known domestic companies, and other maker activities are organized to broaden their thinking, and have a more realistic experience in maker education. Taking Xinhua College of Sun Yat-sen University as an example, a student self-government organization, Center for Science and Technology Application and Innovation (referred to as "Science-Innovation"), is set up under FabLab Innovation Center, which plays an important role as a link: internally, it encourages students to innovate, create, and make. Based on the actual situation of the development of FabLab Innovation Center, it makes full use of teaching resources, carries out innovation and entrepreneurial activities, and conducts extensive and friendly cooperation activities with student clubs and student organizations to promote the thinking and spirit of maker; externally, the students of the "Science-Innovation" Center always uphold Fab Lab's spirit of innovating, opening, and sharing, participate in various types of innovation, creativity, and maker activities, and learn from and exchange with makers all over the world, which not only improves students' level of general knowledge and comprehensive literacy, but also improves the visibility of our school in such innovation and maker activities and forms a new type of education sharing.

C. Establishment of "Interdisciplinary Creative Design Challenge" Course Based on Fab Academy

We practice makers' spirits of "open, green, and sharing", share MIT's "Fab Academy" courses online, strengthen exchanges with maker labs in other colleges and universities, and share maker learning resources on the Internet platform. We establish "Interdisciplinary Maker Education", and carry out a seminar-based learning model, in which there are different makers that are good at text sorting, hardware development, and software operations. Students are divided into groups to fully tap their skills and improve their interpersonal communication, teamwork, problem-solving ability, complement each other's advantages of disciplines, and complete the creative activities of works together. Students are encouraged to combine their own research directions, personally identify problems and solve problems by themselves, so as to learn more actively and more specifically. Students are not only the main bodies of maker activities, but also are active communicators and "liaisons". Students from different majors and discipline backgrounds collaborate through maker activities, and promote the close relationship between teachers and the lab at the same time, achieving a deeper "discipline intersection". Compared to traditional teaching, the "Interdisciplinary Maker Education" curriculum not only changes from "requiring me to learn" to "I want to learn", but also develops the state of "teachers and students learning together" into "teachers and students learning from each other". Through the curriculum's creative projects, they learn from each other, grow together, and even exercise the ability to develop or even operate products, which makes them more adaptable to the development of the times and social processes.

TABLE I. COMPARISON BETWEEN MAKER EDUCATION MODEL OF FABLAB INNOVATION CENTER AND MIT'S FAB ACADEMY COURSE

Maker Education Model Independently Developed by FabLab Innovation Center	**MIT's Fab Academy Course**
Lecture I: Introduction to the Laband Preparing for the Class Lecture II: Tool Learning and Basic Theory Lecture III: 2D/Cutter/Laser Cutting Machine Lecture IV: 3D/Scanner/Printing Technology Lecture V: Control of Large CNC Machines Lecture VI: Electronic Circuit Design and Production	principles and practices, project management … … … applications and implications invention, intellectual property, and income And other courses for a total of 18 weeks

D. Schools, Enterprises, Teachers, and Students Work Together to Create a Multi-dimensional Maker Teaching Platform and Build a Model of Applied Maker Talents

We establish an on-line self-learning platform, and construct and practice O2O training mode for undergraduate applied makers. Through the online teaching website resource library and offline teaching, students will not have to spend too much time focusing on technology in learning the open source development and application modules, but can focus more on the proposal of creative ideas, which improves students' levels of self-analysis, practice and innovation. By learning the digital equipment in the laboratory, they create the project work they want. Universities and high-tech development companies cooperate in production and research, to provide hardware support for colleges and universities that are willing to involve in project development and research on the technologies of the Internet of Things. School-enterprise cooperative training programs will greatly reduce training time and training cost after the companies recruit talents, and actually solves the employment problems for some of the students. In addition, companies can obtain more innovative opinions through the cooperation in the project, and better help their senior innovative applied talents to complete the project, bringing further benefits to the company.

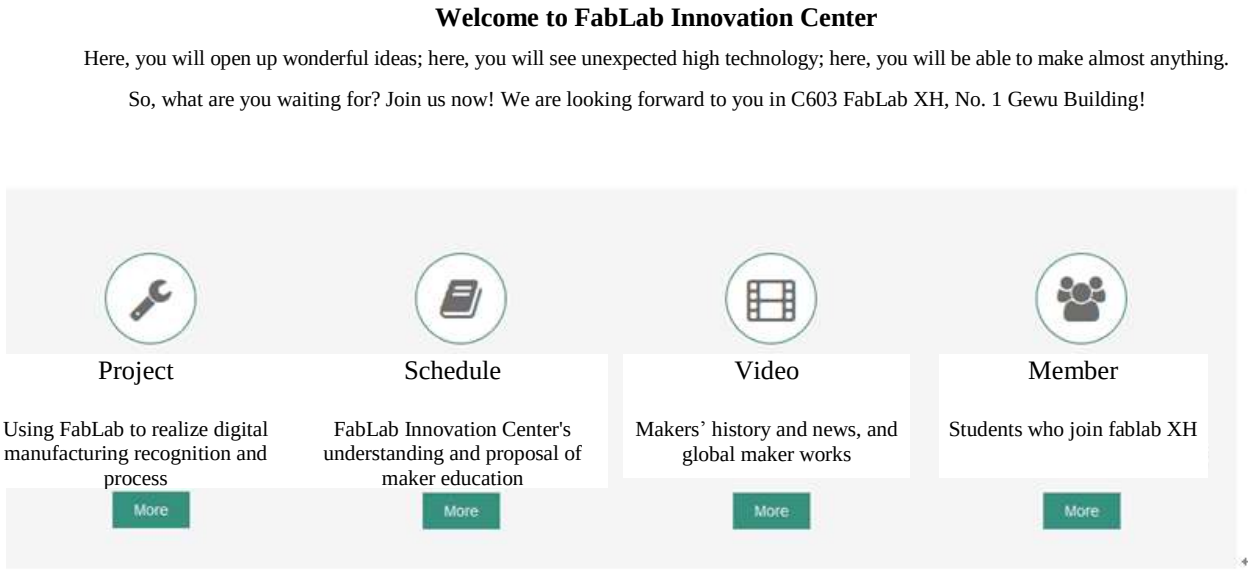

Fig. 3. Maker teaching resource sharing platform.

V. CONCLUSION

The maker education and training in colleges and universities is an important work under the new normal of education development. The work of maker education is still at a stage of development based on the higher education system. The purpose of this paper is to analyze the status quo and existing problems of the current development of maker education in colleges and universities, and put forward the basic conditions to support maker education, and then propose a targeted maker training model for colleges and universities. The ideas and solutions of maker training model mentioned in this paper have been continuously explored by Xinhua College of Sun Yat-sen University since 2014, and the Fab Lab jointly established with MIT is taken as a platform, which is equipped with specialized site and supporting basic digital equipment and tools, a dedicated teaching website is established, which pays attention to the integration and complementarity of teachers and students in all departments of our school, and integrate the training of makers into a special interdisciplinary creative design challenge course to train students' abilities in innovation, creativity, and entrepreneurship, so as to promote employment. It is hoped that our school's specific practice can provide reference for maker training in other colleges and universities.

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