A Trans-regional Online and Offline Fusion Lab Teaching Practice Through Cross-university Cooperation

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***Abstract—Work in Progress*: This Innovative Practice Work in Progress Paper presents how a cross-regional online and offline mixed teaching practice has been carried out by coordinating multiple local universities' laboratory resources. Owing to the COVID-19 epidemic, students could not go back to the campus but stay home all over the country. To work with an electronic system design and implementation project in the Electronic Technology Projects course, students in each team need a public physical workplace equipped with the necessary tools and instruments for circuit debugging and implementation. By utilizing local universities' laboratory resources near their homes, students of the same group could have face-to-face discussions and get offline support from local university laboratory teachers. Each team could also communicate online with course teachers on the technical scheme, detailed design, and fault debugging. While online education can share virtual teaching resources, cross-regional online and offline fusion education can further realize the sharing of entity teaching resources. Twenty-three students have fulfilled their projects in eight local universities under online and offline guidance. Such a teaching attempt has also promoted in-depth cooperation between teachers and students across universities.**

Keywords—lab teaching, online and offline fusion teaching, cross-university cooperation

I. INTRODUCTION

In 2020, the regular teaching order of colleges and universities worldwide was significantly impacted by the COVID-19 epidemic. As a remedial measure, many colleges and universities have launched online teaching. When students could not return to school as usual, online education has solved a large part of the problem. In many theoretical courses, lectures and discussions were smoothly conducted through live broadcast and video conference platforms.

Although online teaching works well for theoretical courses, it cannot meet all needs of lab teaching, especially those focusing on comprehensive practical training. To carry out experimental education during the epidemic period, many educators have made various beneficial attempts. Remote labs made it possible for students to access real instruments and equipment through Internet [1]. A Virtual Instrument Systems In Reality (VISIR) was used at the University of Georgia for the online lab. By VISIR, students could wire on a virtual breadboard and control a digital oscilloscope [2]. In [3], a set of portable lab devices was delivered to each student for doing circuit experiments at home. Although these attempts and efforts provided some solutions for the experimental teaching of specific courses in some particular fields, comprehensive practical training still could not be well addressed, especially those that require team cooperation.

For example, in learning the course Electronic Technology Projects at Tsinghua University, students organize groups of three to five and work on an electronic system design and implementation project. To work with such a project, students in each team need to work together in a public physical workplace equipped with the necessary tools and instruments for circuit debugging and implementation. Online teaching alone is not enough to cover these requirements.

An innovative cross-regional online and offline fusion teaching practice has been carried out by coordinating multiple local universities' laboratory resources. In the course, students freely chose topics for their projects around the theme of Human Health and Environmental Monitoring. They then utilized the local university's laboratory resources near home to carry out their project work. Each team communicated online with course teachers on the technical scheme, detailed design, and troubleshooting. Simultaneously, students of the same group could have face-to-face discussions at the local university laboratories and get offline support from local teachers.

While online education can share virtual teaching resources, cross-regional online and offline fusion education can further realize the sharing of entity teaching resources. Through this innovative teaching mode, twenty-three students fulfilled their projects in eight universities across the country under the teachers' online and offline guidance. Besides the open topic selection around the course's theme, some students also got trained from local universities' characteristic teaching resources. For example, four students joined the particular training class for the National Undergraduate Electronic Design Competition at Nanjing University of Information Engineering. Two other students took advantage of the Intelligent Car Innovation Laboratory of Kunming University of Science and Technology.

Such a teaching attempt has also promoted in-depth cooperation between teachers and students across universities. Two teachers from Zhejiang Normal University participated in the course wrap-up session and made detailed comments on the reform and construction of similar courses. Many students mentioned in the project summary report that by working in local universities' laboratories, they completed the course study and got an opportunity to exchange views and work with local teachers and students.

II. THE COURSE

A. *Project-based Training*

Electronic Technology Projects is a project-based comprehensive practical training course based on the previous learning of digital and analog electronics. For students of Automation Department, it is a 3-credit compulsory course. In the summer term of sophomore year, students are required to work on the design and implementation of an electronic system in two consecutive weeks.

There are mainly two aspects of this project-based training. One is the design and fabrication of analog circuits based on modern analog devices, for example, the design, simulation, and fabrication of power supply circuits. The second is designing and implementing a digital system based on FPGA (Field Programmable Gate Array), MCU(Micro Controller Unit), or other embedded processors.

Each year, the course sets up a theme for the project-based learning activity, such as smart homes, intelligent transportation, and intelligent robot. Students can freely choose project topics around this theme and develop their specifications. In such an free topic selection mode, the content of the project is no longer determined and assigned by the teacher. Students are motivated to set up innovative functional specifications for their project and realize them through team cooperation. Moreover, in implementing the project, teachers no longer have ready-made answers to students' questions. When encountering problems, as the owner of the project, students tend to explore more independently.

B. Teamwork

The course learning process mainly includes the introduction lecture, project topic selection, system design, system implementation, and project defense. Students work in groups of three to five to accomplish the project.

In the project topic selection stage, it is necessary to clarify the objectives and tasks, do literature reading, work out the technical scheme, and start the circuit design and simulation. At the end of the course, the circuit must be welded on the universal board or made into a Printed Circuit Board (PCB). Frequently used components include instrument amplifiers, Analog-to-Digital Converters (ADCs), Digital-to-Analog Converters (DACs), power management chips, and various connectors. All students can keep their project works.

Compared with an individual project, through group cooperation, a more complex electronic system can be designed and implemented in two weeks, and students' sense of teamwork can be enhanced.

C. Teaching Facilities

To fulfill the course teaching for such an open-topic project-based training, online education alone is not enough. Although topic selection discussion and project defense can be carried out online, students need an offline public environment for teamwork to make different parts of a real electronic system.

Usually, a physical laboratory is required for the course. It is equipped with some commonly used electronic components, circuit debugging instruments such as signal generators and oscilloscopes, PCB printing machines, and 3D printers, as well as soldering irons, drilling machines, and other tools. Although students can also obtain all the components through online procurement, having some necessary parts at hand can speed up the progress of the project in a limited period of two weeks. While team discussions can also be conducted online, face-to-face conversations are usually more effective for hardware-oriented projects.

Also, even though teachers can provide students with distance guidance, offline intervention guidance can be more effective and necessary when encountering particular operational problems. For example, if students cannot successfully solder a chip onto a PCB, hand-in-hand help on-site is undoubtedly more effective than long-distance methodological instructions.

In the summer of 2020, sophomores in Automation Department of Tsinghua University were supposed to stay in the department laboratory to learn Electronic Technology Projects. However, affected by the COVID-19 epidemic, they could not go back to the campus but stay home all over the country. To minimize the impact of the outbreak on this curriculum, teachers have come up with a solution to realize online and offline integrated lab teaching by cross-university cooperation. Students took advantage of the teaching facilities of local universities to work out the curriculum projects.

III. Preparation for the Teaching

Before the trans-regional online and offline mixed lab teaching was put into practice, the course instructors had done much time-consuming communication with course students and local universities.

A. Questionnaire

First, we made a questionnaire to investigate the distribution of colleges and universities near the students' homes. The questionnaire mainly included the following questions:

1) Are you willing to join the learning plan?

2) Which city are you in?

3) What are the science and engineering universities near you, and what are the distances?

Please make a comprehensive ranking of the universities according to the distances from home and the requested laboratory resource they can provide.

Within hours after we released the questionnaire, 156 students who participated in the course responded, which reflected that students were very supportive of such a learning plan. After staying at home for quite a few months, they were eager to go back to the campus to study with classmates, even if it was not their original campus.

B. Student Grouping

According to the students' feedback in the questionnaire, university candidates within 50km away from homes were selected. If multiple students chose the same local university with high priority, they were formed into a team. For the rest of the students, a WeChat group was set up for students in each province. Through communication and coordination, each WeChat group reached convergence on choosing the appropriate universities within the region.

Nearly ten students could not join any teams because there were no universities within a few hundred kilometers from their homes. As an alternative, they might choose to complete a mini-project with the portable lab devices they received in the spring term.

C. University Communication

The cross-university teaching plan has been greatly supported by Tsinghua University both at the university and department level. Many teachers and administrators contributed to the communication and coordination with local universities. An online document was established to keep an up-to-date record of the communication progress.

This work was propelled in parallel with student grouping. Once a new team was established, the requested university would be added to the online form for further communications. Meanwhile, once a university was successfully connected, the information would be published to students so that nearby students could join.

Finally, a total of 18 universities were successfully arranged to accept 55 of the 156 students. More than 20 colleges and universities were pending due to the local epidemic prevention and control policy. The contact teachers of each local university were invited to the WeChat groups of the student teams for subsequent follow-ups.

D. Schedule Adjustment

The course was initially scheduled from August 31 to September 11, lasting up to two weeks. In order to flexibly adapt to the school calendar of local universities, an extra class window was added in July and August, respectively.

Among the 18 groups at the above 18 universities, one team was scheduled in July, seven in August, and the remaining ten in September. As the epidemic eased, the students returned to Tsinghua University at the end of August. Therefore, in total, eight out of the 18 teams carried out the course learning through online and offline integration mode by utilizing the resources of local universities.

IV. Implementation of Online and Offline Fusion Lab Teaching

With the support of laboratory resources and teachers from local universities, the whole process of curriculum teaching was hit the ground in the way of online and offline integration.

A. Introduction Lecture

The introduction lecture was conducted online, and all course students participated in the class through the video conference platform. At the end of the introduction class, there was a session for questions and answers.

The main content of this lecture included the introduction of teaching objectives and scope, course arrangement and organization, project topic selection guidance, and grading rules of the course. As an echo of the epidemic situation, the theme of 2020 was titled "Human Health and Environmental Monitoring." Students could design and implement an electronic system for intelligent detection of body temperature, heart rate, blood pressure, ambient temperature, humidity, and atmospheric pressure. It could also be a prototype system of small electronic equipment to assist in physical exercises such as pedometers, step testers, and grip strength meters.

Fig. 1 shows a basic structure of an electronic system and illustrates the scope of project work within this framework. For example, the system must include some sensors and actuators, an embedded processor, and some power management circuits. Analog amplification and filtering, digital-to-analog, and analog-to-digital conversion modules are optional.

In the course grading, the overall function of the system was evaluated first. Then the specific workload, difficulty level, and innovation in the implementation of each module were investigated in detail.

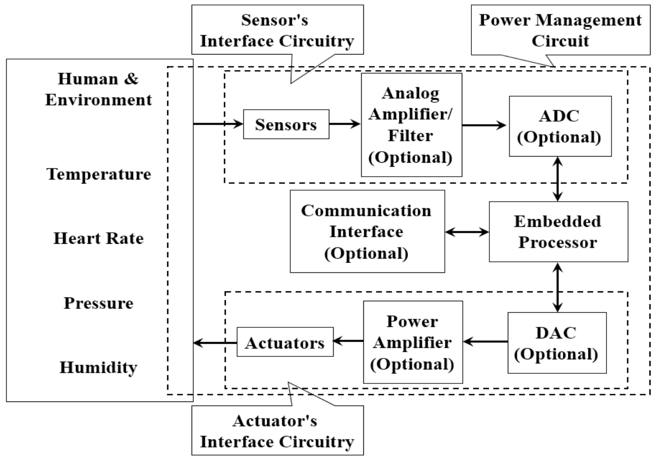

Fig. 1. System framework and the scope of project work.

B. Project Topic Selection

Team members discussed project topic selection offline in the local university's lab and then discussed with course teachers online.

Typically, students in each group would communicate with the teacher twice to finalize the topic selection. The first online meeting was for discussions on the preliminary idea of the topic. The teacher would give suggestions on the orientation of topic selection, features that were likely to be worked out in two weeks, and other possible innovation directions. The second one was for going over the formal topic selection report. Teachers and students discussed and agreed on the detailed technical scheme, task allocations among members, and schedule plans.

For example, three students near the Southwest University of Science and Technology intended to build an intelligent sleep monitor. When working out preliminary functional planning, they had a video conference with the teacher.

They designed to use multiple sensors to detect the temperature and smoke concentration level in the room and the sleeper's heart rate and skin resistance. In their plan, they tried to have a deep analysis of the relationship between sleep quality and environmental parameters by comparing the gauged human body and ecological data [4].

The instructor highly commended the creativity of this project topic. However, since the course training mainly focused on interface circuitry, students were not encouraged to put too much emphasis on the data analysis part. Also, it was not easy to obtain enough meaningful data for analyzing the relationship between sleep quality and environmental data in such a short period. Instead, the instructor suggested that they could automatically control the air conditioning according to the detected temperature.

At the second meeting with the teacher, the three students reported a new version of the function specifications followed by the system modules' technical scheme and the related circuits' detailed design.

C. System Design and Implementation

In the system design and implementation stage, local universities played a key role.

First, they provided a space for free discussion among group members. Second, the ready-to-use instruments, equipment, tools, components, and consumables in the lab greatly facilitated students' circuit making and debugging. Commonly used low-cost parts and consumables were provided free of charge. In contrast, particular or expensive ones were obtained through online procurement. Finally, the local teachers provided students with instant offline advice. They also gave students hand-in-hand guidance in component welding and circuit fabrication.

At this stage, students could also quickly ask the course teacher for help via WeChat. In case of complex problems, they could also discuss with the teacher through video conference. For example, when the two students in Zhejiang Normal University were working on the project of "Visual Glasses," they encountered some problems in the serial communication between two MCUs. They held three video conferences successively with the teacher to discuss in detail and finally conquered the bug. Since the process of fault analysis and elimination made them feel very rewarding, they did a thorough review and wrote more than ten pages of debug log [5].

D. *Acceptance Check*

At the end of the project, the course teacher did the online acceptance check via a video conference.

Students remotely demonstrated the overall functions of the project work in the video conference. The teacher asked the details of each module and kept a record for subsequent workload and difficulty level assessments. In addition to the successful implementation of the functions, students can also demonstrate those failed attempts. By doing so, students could be stimulated to make more bold creative attempts. Besides, each group of students was required to record a full video for their project work.

Fig. 2 shows a hand gesture imitation robot developed by four students in the innovation laboratory of Jilin University. On the left is the manipulator model they made using a 3D printer, and on the right is a human hand with a glove. Sensors such as bending strain gauges and gyroscopes sewn inside the glove can detect the human hand's swing in the left-right or front-back dimension and the bending action of different finger joints. According to these inputs, the system controls the manipulator to imitate the action of the human hand through a series of steering engines [6].

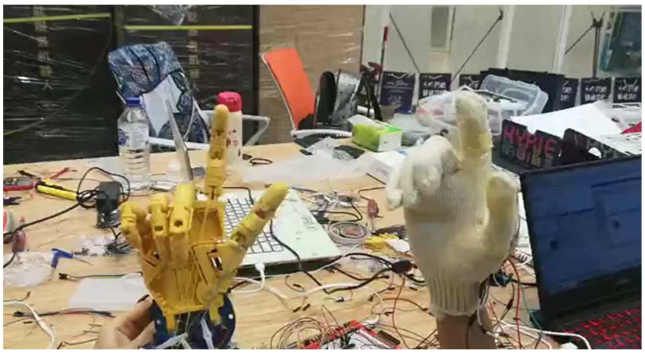

Fig. 2. Hand gesture imitation robot.

TABLE I. PROJECT WORK OF THE SEVEN GROUPS IN AUGUST

Group	Name of Project	Grading
1	Visual Glasses	A
2	Intelligent Sleep Monitor	A+
3	Intelligent Air Conditioning Control System	A-
4	Intelligent Multimeter	A-
5	Hand Gesture Imitation Robot	A
6	Automatic Tracking Intelligent Car	A-
7	Simulation Circuit Design for a Process Control System	B+

V. THE RESULTS

At the end of the two-week course, all the teams participated in the video conference for project defense. Centralized project defense provided students an opportunity to learn from each other.

In the course window of August, seven groups participated in the project defense meeting. As shown in Table 1, five of these groups worked on open topics. According to the first group, in Zhejiang Normal University, with a comfortable environment, a complete range of instruments and equipment, and the patient guidance of teachers and senior students, they obtained excellent learning and hands-on practice experience. The second group stated that their work accomplishment had well reached their expectations. They were deeply impressed by the course teacher, who was far away in another city but always responded instantly when being asked for help. The sixth group utilized the Intelligent Car Innovation Laboratory of Kunming University of Science and Technology to carry out the design and development of an intelligent vehicle. The laboratory not only provided site support for debugging smart cars but also a 2-week accommodation. The last group studied a process control simulation system in Yangzhou University's scientific research laboratory. According to them, the project work was exciting and challenging.

As can be seen from Table 1, all of the seven groups had achieved good results. Six of the groups were graded as A- and above.

VI. CONCLUSION AND FURTHER THOUGHTS

The teaching practice showed that it was successful for students to complete the comprehensive practical training courses by using the laboratory resources of local universities. One enlightenment is that it can be a feasible solution when students cannot return to school for unexpected reasons. Under such an online and offline mixed experimental teaching mode, students can obtain the online guidance of course teachers and have the environment and equipment needed for offline teamwork.

During the epidemic period, the rapid launch of cross-university cooperation benefited from the existing communication foundation between university teachers. Conversely, this cross-school collaborative teaching has dramatically promoted substantive exchanges between teachers and students from different universities. Thus, another enlightenment of this teaching practice is that we should strengthen the cooperation among universities even in the regular period. On the one hand, it can make students benefit from the characteristic teaching resources of different universities. On the other hand, it can promote the construction of related curriculums and laboratories.

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