Challenges and innovations in online teaching during the outbreak of COVID-19 in China

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***Abstract*—At the beginning of 2020, coronavirus disease 2019 (COVID-19) spread quickly throughout China. For the health and safety of faculties and students, all schools and universities were required to postpone their spring semester; however, the Ministry of Education hoped that teaching and learning could be facilitated to decrease or even eliminate the negative impact of the postponement on the students' subsequent self-development. Taking the "Principles of Electric Circuits" course as an example, this paper presents an innovative online teaching scheme for fundamental engineering courses, including pedagogical design and interactive methods in lectures. The students' feedback was collected using delicately designed questionnaires and the results demonstrated that our online teaching scheme achieved an effect no less than that from traditional in-classroom teaching, with even better student interactions using the online networks.**

Keywords—COVID-19, online teaching, RainClassroom, interaction

I. INTRODUCTION

Online teaching has been available for many years, and massive open online courses (MOOCs) probably was the most famous and widespread form in the past decade [1,2]. However, online teaching on campus mostly plays an auxiliary role to traditional classroom teaching. This role was completely changed in all schools in China at the beginning of 2020 because of the spread of coronavirus disease 2019 (COVID-19), which was the same currently all over the world. Students and teachers were required to stay in their own home for the sake of their health until the end of the outbreak, while any negative impact on the students' following development needed to be minimized. Therefore, online teaching became the dominant or even only choice instead of the traditional in-classroom teaching method during the current situation in China.

In accordance with the unified requirement of our university, massive online teaching was performed to adhere to the course timetable determined in the previous semester. Thus, the time conflicts of various courses could be avoided as much as possible and the students can smoothly shift to normal in-classroom teaching as soon as they return to the campus. As an example, our "Principles of Electric Circuits" course is the first fundamental course in the disciplines of electrical engineering and computer science. In our university, about 1000 students complete this course every year, which makes such a massive long-term online teaching course challenging with the aim to obtain learning quality equal to that of traditional classroom-based teaching.

Online teaching was not a simple matter of shifting teaching styles from the classroom to the Internet [3]. The methods, tools, and even content of online teaching and learning should be adjusted systematically; therefore, a thorough pedagogical design was required. This paper presents the process and results of this innovative online teaching scheme in detail. The ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model of instructional design theory was applied. First, the authors discussed and analyzed the situations they faced several times, including online teaching objects, technology routes, and hardware and software requirements for the students. All links of the massive and long-playing online teaching course were then designed specifically. Special courseware and live broadcast systems for this type of online teaching were developed accordingly before the semester started. The online teaching of the course was then implemented using the RainClassroom toolkit. The course is proceeding smoothly to date and is being improved continuously based on the students' continuous feedback. The statistical analysis of the large amount of data recorded by RainClassroom provides information for an objective and reliable evaluation, and the questionnaire feedback informed about the subjective feeling of the students on the online teaching course. According to these data, we developed, improved, and implemented our design of online teaching, new teaching methods, modes, and even content as we went. Consequently, a student-centered closed loop of online teaching was formed with an online teaching effect hopefully equal to that of traditional in-classroom teaching. From some aspects, online teaching was even better, such as the effect of interactions during lectures using bullet subtitles and being able to play back the lectures afterwards.

II. ANALYSIS AND PEDAGOGICAL DESIGN

Online teaching is quite different from traditional in-classroom teaching and even recorded broadcasts are quite different from live broadcasts. Therefore, a special pedagogical design for online teaching is necessary. The most common misunderstanding of online teaching is to consider online teaching as simply uploading a recorded lecture or even running a MOOC [4,5]. Although this is probably the easiest way, it is not necessarily the best way. In this way, lecturer and students have no interaction during the lecture, and the explanation of knowledge is general and lacks pertinence. Therefore, the authors chose live broadcasts to

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give lectures, while recorded broadcasts or MOOCs at some points were used as additional materials. The following discussion refers to this mode, i.e., live broadcasts supplemented with MOOCs and recordings of earlier lectures [6].

The disadvantages of online teaching mainly include the following:

(1) It is more difficult for students to concentrate for a long time during online teaching;

(2) Teachers cannot obtain instantaneous feedback from students by eye contact or their body language;

(3) Peer learning among students decreased significantly;

(4) Personal attractiveness from the teacher is inevitably decreased without face-to-face communication.

It was hoped that online teaching could essentially be equal to in-classroom teaching; therefore, to make up for the above disadvantages, an elaborate pedagogical design for online teaching is required. The pedagogical design includes break adjustment of each lecture; content distribution before, during, and after lectures; rich and effective interaction during lectures; and the effective management of the learning process. Using these methods, the teaching quality and learning experience are expected to be maintained to the standards of traditional teaching as much as possible.

A. Break Adjustment for Each Lecture

The length of traditional lectures is usually about 1 hour and 30 minutes, with only one break of 5 minutes after 45 or 50 minutes of teaching. With the consideration of the impacts on eye health or learning efficiency for students, a continuous 45-minute learning session is a little too long for the online environment. According to research from education studies, we divided the 90-minute lecture into three parts, with 25 minutes of teaching and a 5-minute break (Fig. 1). The length of each part is not regulated strictly, as the lecturer can modify it according to the content.

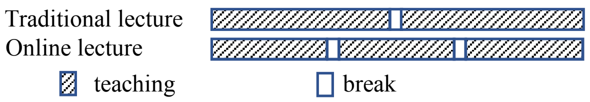


Fig. 1 Break Adjustment for Each Lecture

B. Content Distribution before, during, and after Lectures

Because breaks take more time and network delay should also be considered, the time that can be effectively used for knowledge delivery in each lecture is consequently reduced. Therefore, some knowledge must be delivered outside the lectures using proper methods. The teachers should carefully divide the content into three parts, which are sent to students before, during, and after class. The slides must be modified accordingly.

Taking Lecture 2 as an example, the lecture contains the following content: explanation of terminologies of circuit topology; Kirchhoff's current law and voltage law (KCL and KVL); linear resistor and its characteristics; independent sources and their characteristics; dependent sources and their characteristics; and the 2b method.

All content is taught in the traditional in-classroom lecture; however, it is impossible to teach the same content in the same length of time with the same effect during a live online lecture. Therefore, content was divided into three parts. The most important content must be discussed thoroughly during the lecture. The fundamental knowledge required to understand the key content can be sent to the students before the lecture in the forms of PowerPoint slides, audio or video recordings, or MOOCs. Extended information on the key content is sent after the lecture for optional reading. With regard to Lecture 2, the content division was:

Before lecture: explanation of terminologies of circuit topology.

In lecture: Kirchhoff's current law and voltage law (KCL and KVL); linear resistor and its primary characteristics; independent sources and their main characteristics; and dependent sources and their main characteristics.

After lecture: secondary characteristics of linear resistor, independent and dependent sources; and the 2b method.

The content division can be generalized as shown in Fig. 2.

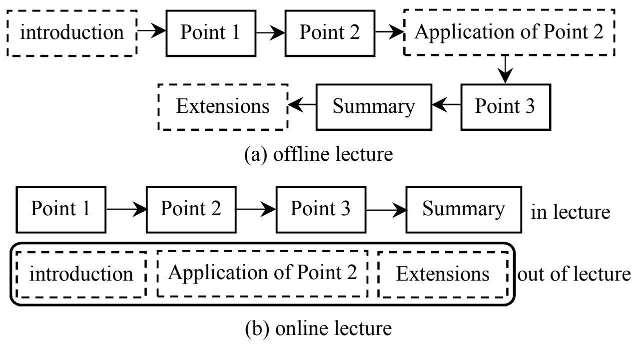


Fig. 2 General Rule of Content Division for the Lecture

Content division leads to a new problem, i.e., effective learning outside the lectures must be ensured, otherwise the quality of teaching and learning during the lectures will decline. Some information technology (IT) tools combined with advanced pedagogical ideas, such as RainClassroom, were applied to resolve this problem effectively.

C. Learning Process Management

Compared with traditional in-classroom teaching, we cannot meet students in the classroom twice a week, thus we get no direct sense of the learning status of each student. Therefore, effective learning process management becomes more important, including delivering preview and review materials, stimulating active interactions during the lecture, assigning and correcting homework online, and obtaining the completion of learning tasks of all students in time.

To fulfill these functions conveniently and effectively, a powerful integrated platform is urgently needed. The following functions are necessary so that lecturers are able to focus on delivering the content itself:

- Distributing teaching materials conveniently and efficiently before and after lectures, including text, audio, and video files.
- The learning status of all students can be described in detail as long as the lecturer wants, including the completion of preview and review and learning effects in lectures.
- Convenient and highly efficient interaction during the lecture.

- Homework can be assigned and checked online, while students can complete it offline by handwriting, with which they are familiar and can save time.
- The data for the whole teaching and learning process can be recorded automatically for further analysis and evaluation.

A special teaching and learning-oriented smart toolkit independently developed by Tsinghua University called RainClassroom met almost all of these above requirements. RainClassroom is a PowerPoint add-in that integrates with WeChat, the most popular smartphone application in China.

III. Implementation and Instant Evaluation of Online Teaching

There is no doubt that live online lecturing is the key link in the innovative teaching scheme. To attract the attention of distant and distributed students, rich interaction during the lecture is necessary and effective. RainClassroom is probably the best toolkit to satisfy our requirements owing to its professional design of various and highly efficient interaction methods.

A. *Instant Learning Evaluation*

Single-choice, multiple-choice, and fill-in questions are sent during the live online lecture, and the students are required to answer within a designated time. The length of time can be set by the lecturer according to the difficulty of the questions and it can be increased or decreased conveniently according to the students' submissions. When the time completes, the answer distribution is shown instantaneously as a bar chart (Fig. 3). Thus, the learning effect of the students concerning the knowledge referred to in the question is evaluated accurately and lecturers can flexibly adjust their teaching according to the evaluation results.

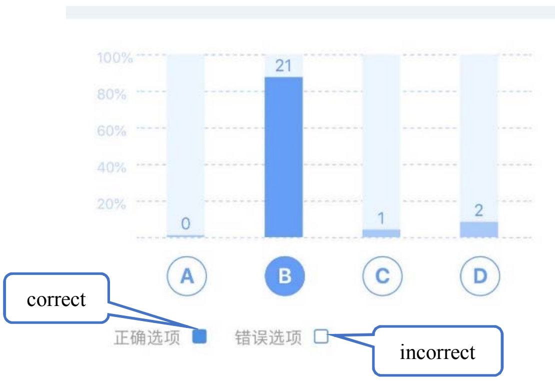


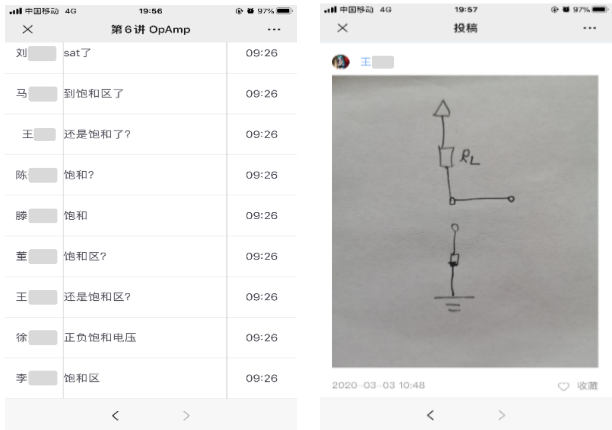
Fig. 3 Bar chart for a single-choice answer

B. *Instant Feedback*

Bullet subtitles and draft submissions of text, graphs, and short videos during lectures are two other effective ways to receive instant student feedback. Compared with the required time-limited choice questions, these two ways are free and open with less pressure on the students.

Bullet subtitles are suitable for interactions using brief expressions because they fly across the screen as soon as they are submitted by the students. This channel can be opened or closed by the lecturer to avoid the students becoming distracted. Meanwhile, draft submission is suitable for interactions using more complex graphs and equations, which are an important part of engineering courses. Draft submission can be required by the lecturer or spontaneously submitted by students at any time. However, whether the submitted draft is displayed during the class or not is determined by the lecturer. Both bullet subtitles and drafts are instantaneously synchronized to the lecturer's smartphone (Fig. 4). A word cloud composed of words where the sizes of the words represents how often they appeared in bullet subtitles can be generated in real time during the lecture (Fig. 5), The word cloud can be used as a qualitative analysis of the bullet subtitles.

An inspiring phenomenon appeared in our courses during the last month, i.e., interactions were even more active and effective than those in traditional in-classroom lectures. Because most Chinese students are reluctant to express their ideas orally in the classroom, the seemingly anonymous bullet subtitles and relatively private draft submissions make them more relaxed about expressing their ideas freely.



(a) Bullet subtitles (b) Submitted draft

Fig. 4 Real-time data synchronized and displayed on the lecturer's smartphone

Fig. 5 Word cloud

A board-writing function is also available on RainClassroom for lecturers, which is quite useful for curricula that include intensive mathematics and physics.

C. *Real-time Oral Discussion*

In classes with a small number of students, oral discussion is necessary for many lecturers, especially in the flipped classroom, although these classrooms are currently shifted to online virtual classrooms [7]. Unfortunately, RainClassroom does not support bidirectional oral discussions between lecturers and students; therefore, our lectures use Tencent Meeting, a video meeting platform. Some other platforms have similar functions, such as Zoom, Microsoft Teams, and Cisco's Webex. The synchronous adoption of the meeting platform and RainClassroom requires higher Internet performance and the lecturer should confirm that the students have sufficient Internet bandwidth before the lectures begin. In fact, real-time conversation is not an urgent need for classes with a large number of students, e.g., >60.

D. Automatic Recording of Teaching and Learning Data

Although slides can be presented to students in Tencent Meeting, RainClassroom cannot be totally replaced because of its interaction data collection function, which is currently not available on any other platforms to our knowlwdge. All learning data before, during, and after lectures were automatically collected and recorded in the RainClassroom server. A brief summary is immediately sent to the lecturer's smartphone after the class, including the three students with the highest and lowest test scores from the current lecture, participation and accuracy rates for each objective question, and detailed bullet subtitles and drafts (Fig. 6).

More detailed data can be downloaded from the RainClassroom website in an Excel file format and more statistical analyses can be performed by the lecturers themselves.

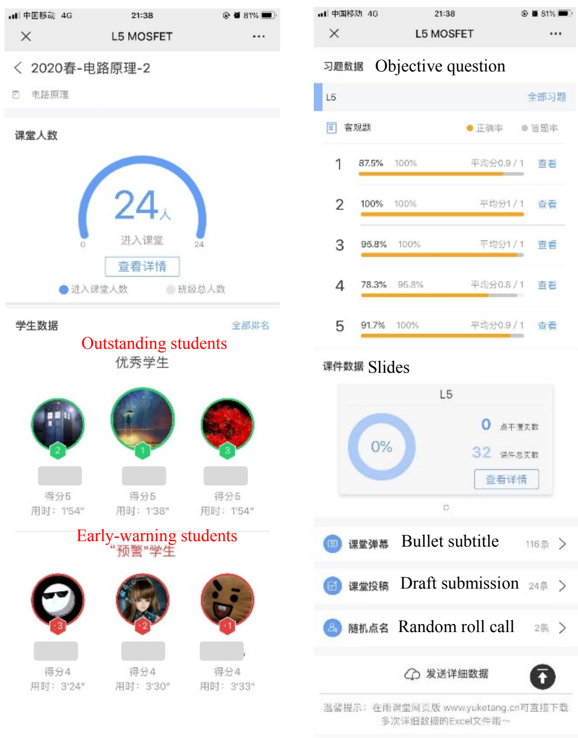


Fig. 6 Brief summary immediately sent to lecturer's smartphone after class

IV. Further Evaluation of Online Teaching

To date, massive online teaching has been performed for 4 weeks at our university. Based on the teaching and learning data recorded automatically by RainClassroom, the teaching effect is digitized and process assessment is possible [8]. Two classes from our course were taken as examples. Class 1 had 24 students and a flipped classroom was adopted, while Class 2 had 128 students and a traditional in-classroom teaching method was adopted.

A. Learning Basis Survey

At the very beginning of the semester, a first round of questionnaires was undertaken, which aimed to find out the students' basic knowledge of electricity and their self-evaluation on their ability to quickly understand new material. Fig. 7 shows the statistical results from a multiple-choice question and a single-choice question. The results show that most students had a weak basic knowledge of electricity and only about 60% of the provided material can be mastered during the lectures according to the students' self-evaluation. Class 1 was a little better than Class 2 in these two indexes.

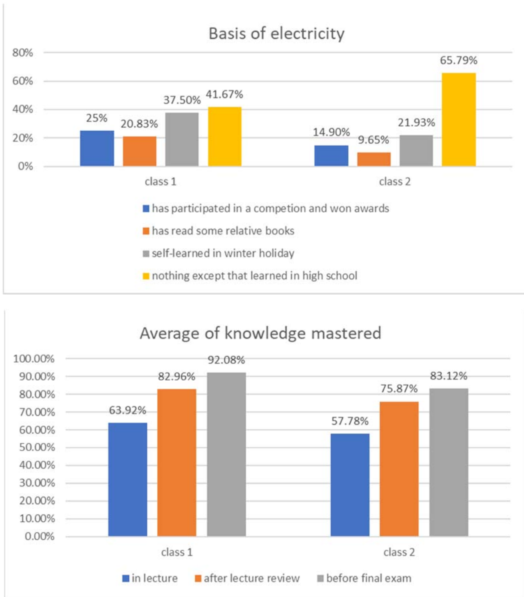


Fig. 7 Statistical results of the first survey

B. Quantitative Evaluation Based on RainClassroom Data

A great amount of data was collected and recorded automatically on the RainClassroom server over the past 4 weeks, including the answers from all time-limited exercises, bullet subtitles, submitted drafts in lectures, respective times of previews and reviews, and even photos of handwritten homework. We focused on two quantitative indexes: i.e., the accuracy rate of time-limited exercises and the number of bullet subtitles submitted during lectures. The former is an index of passive feedback, which can represent the effectiveness of teaching, while the latter is an index of active feedback that reflects the students' willingness to participate. The feedback from these two indexes of the previous two classes is shown in Fig. 8.

In most lectures the accuracy rates of time-limited exercises during the two classes were comparable and the accuracy rate percentage was basically as expected. However, more bullet subtitles per capita were used in flipped classrooms than in traditional classrooms, which meant that the students in small flipped classrooms were more active than those in large traditional classrooms. Furthermore, the curve of bullet subtitles per capita in traditional classes gives us a timely reminder that the students' initiative and participation was decreasing slowly. Perhaps the freshness of online learning was fading away; thus, a special design is required to effectively catch the students' attention and improve their learning achievements.

The numbers of bullet subtitles submitted in both online teaching and traditional in-classroom teaching at the same scale were compared (Fig. 9). Online interaction using bullet subtitles increased greatly during online teaching, which compensated for the lack of face-to-face interactions in traditional in-classroom teaching to a great extent.

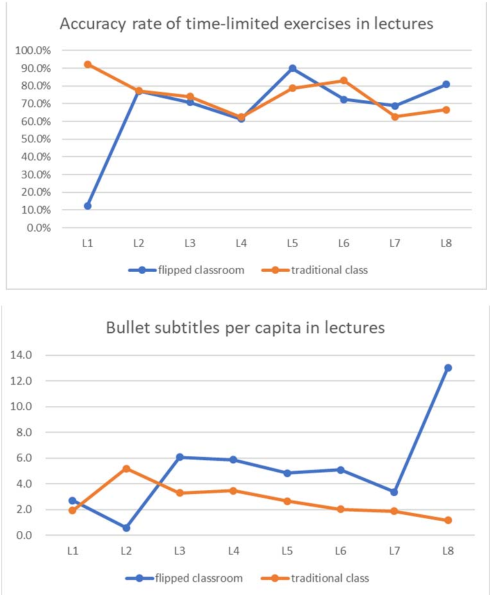


Fig. 8 Accuracy rate of time-limited exercises and bullet subtitles per capita from the two classes

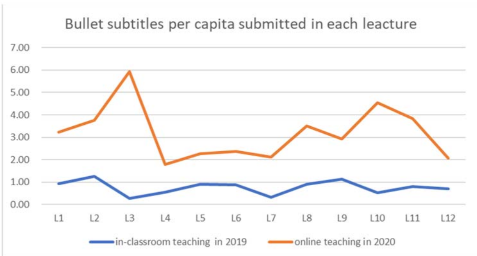


Fig. 9 Number of bullet subtitles per capita from online and in-classroom teaching styles

C. *Qualitative Evaluation by Questionnaires*

The qualitative indexes play an equally important role to quantitative indexes in the evaluation of teaching and learning effects [9,10]. Several qualitative questions were listed in the second questionnaire, which was sent to students at the end of the fourth week. A group of questions concerned how helpful RainClassroom's main functions were. The results are shown in Fig. 10: i.e., the higher the score is, the more helpful the function is considered. The students in the two classes gave different preferences, which was mainly because online teaching in these two classes used different modes.

Another group of questions concerned the students' subjective experience of the course, such as learning pressure, teaching in lectures, completion of extracurricular learning tasks and satisfaction with the course in a whole. Fig. 11 shows the results, the darker the color is, the larger the pressure is, or the better the experience is. Students in the flipped classroom (Class 1) felt more pressure than those in the large class (Class 2); however, they had a better experience of teaching and task completion, which led to a higher degree of satisfaction with the course. Correlation analysis based on SPSS built in the survey tool showed that

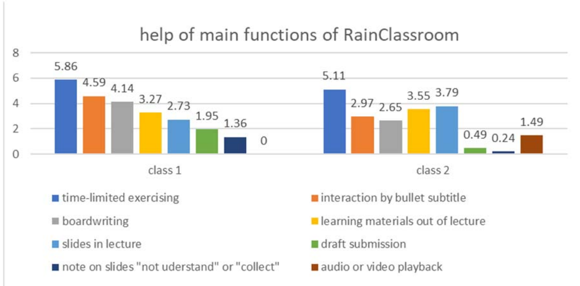


Fig. 10 Evaluation of the help derived from RainClassroom's main functions during two classes

teaching in lectures and completion of learning tasks have positive correlations with the students' satisfaction with the course, while learning pressure has no relationship with the students' degree of satisfaction.

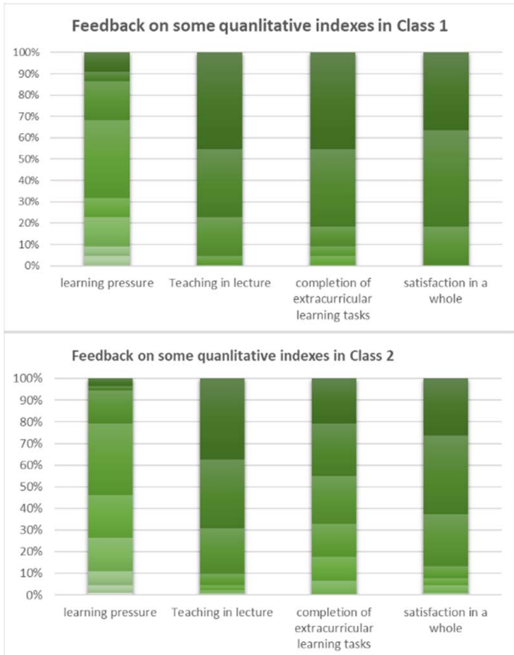


Fig. 11 Evaluation of the students' subjective experience of the two classes

V. CONCLUSIONS

The outbreak of COVID-19 brought great challenges to teaching and learning in universities; however, it simultaneously stimulated many innovative ideas and models of teaching with the help of advanced IT. An effective and massive online teaching model was proposed and realized by applying the ADDIE model to a fundamental course.

The advantages and disadvantages of online teaching as well as online teaching targets were first analyzed and then a special design for this online teaching model was produced, including increasing break times, teaching content division, rich interactions, and optional audio/video conversations. As a powerful IT platform, RainClassroom efficiently enabled the smooth implementation and evaluation of an innovative online teaching mode through its automatic data collection that recorded and analyzed the whole teaching and learning process. However, timely feedback collection by questionnaires was still necessary, especially for the qualitative evaluation of online teaching and learning.

The statistical results of our survey showed that the online teaching scheme obtained an essentially equal effect to that of traditional in-classroom teaching. Meanwhile, the scheme also revealed existing problems, such as that it is more difficult to focus on learning for a long time, and class participation decreased with time. Some methods were applied to improve the online teaching process and we believe that blended teaching and learning will become an irresistible trend in the future.

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