

# Transit Traditional Face-to-Face Teaching to Online Teaching during the Outbreak of COVID-2019

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**Abstract**—COVID-2019 outbreak in China at the beginning of 2020. Traditional face-to-face teaching cannot be achieved during the epidemic, and all schools across the country turned to online teaching. However, online education still faces many difficulties, and the most important question is how to ensure teaching quality. In this paper, we discussed some pedagogical approaches, including online teaching with the enhanced design of interactions, learning theories and problem-based learning, which are useful for designing courses. Then, a computer foundation course was taken as an example to show how to transit a traditional face-to-face course into an online course utilizing the pedagogical approaches and conduct teaching adjustment based on students' learning behavior.

**Keywords**—online teaching, learning theory, pedagogical design, teaching adjustment

## I. INTRODUCTION

At the beginning of 2020, COVID-2019 outbreak in China. In order to control the epidemic, all schools across the country postponed the start of school. Meanwhile, higher education institutions turned to online teaching to maintain the teaching process. Transiting face-to-face courses into online courses are not simply publishing content to cyberspace, but a complete set of carefully designed teaching methods, teaching materials such as text, audio or video, and a technical support team. However, due to the suddenness and uncontrollability of the epidemic, only one or two weeks were left for the preparation for online education, which made the work more difficult [1].

In this paper, a course for those who major in computer science called “computer foundation” was taken as an example to show how to transit a traditional face-to-face course into online teaching. The second section of this paper provides an overview of the foundation of pedagogy, including online teaching with the enhanced design of interaction, learning theories and problem-based learning (PBL). The next section describes the pedagogical design of the course. Then we will talk about how to conduct teaching adjustments based on students' behavior data. We collected the data through the learning management system (LMS) and some online tools used in the course. Correlation analysis was conducted between the indicators extracted from the data and students' test scores to figure out which indicators are highly related to their performance. Then, correspondingly, we could adjust the teaching process timely and strengthen the course design in this and the next semesters. Finally, the last section shows the conclusions.

## II. PEDAGOGICAL FOUNDATION

### A. Online Teaching with Enhanced Design of Interaction

Online teaching refers to placing educational resources in cyberspace to form a shared virtual learning environment (VLE). Over the years, incorporating technology into the

teaching process has attracted great attention and provided various ways, such as MOOC, SPOC, and blended teaching model [2]. In the online teaching process, it is very flexible that students can access resources at any time in any place, and teachers could collect students' behavior data through LMS to understand their learning status. However, there are still challenges for both students and teachers. For example, the self-regulation and isolation challenges for students and technological operational challenges for teachers [2]. Because online education does not have regular face-to-face classes, it needs to rely on the initiative of students to complete learning. Moreover, in a distributed learning environment, students may feel lonely since they do not have a classroom environment to interact with the lecturer and other learners. Teachers cannot observe feedback directly and it is more difficult for them to manage students than it in the traditional teaching model. Therefore, interaction is an important approach to ensure the teaching quality in the online teaching process.

Online interaction is commonly regarded as an effective way to enhance online teaching. Through teacher-student interactions, instructors can urge learners to complete learning tasks and get feedback from them. Learners could work together to solve problems and exchange learning experiences through student-student interactions. There are two types of online interaction: asynchronous and synchronous. Asynchronous interaction occurs in delayed time that participants do not have to be online simultaneously. They can contribute to the discussion on their own schedules. Synchronous interaction is commonly supported by live streaming platform or social networking software. It is more efficient that participants can get responses timely when they have problems.

Reference [3] integrated both synchronous and asynchronous discussions in one course, and they found that asynchronous discussion contains more academic words and less social words. Moreover, many studies have shown that social presence in synchronous discussions is higher than in asynchronous discussions. Social presence can reduce loneliness and build trust between individuals, which is crucial in the VLE. These suggest that synchronous and asynchronous discussion play different roles in the learning process. The synchronous chat is mainly used to build a trusted VLE, in which students can obtain a sense of belonging and reduce loneliness. The asynchronous discussion is considered as an extension of the teaching content. It allows students for more in-depth discussions and more thoughtful learning and can promote their reflection, knowledge construction and self-assessment. Integrating the two types of interaction in one course can achieve complementary purposes.

### B. Theories of Learning

Theories of learning explain how learners absorb, process, and retain knowledge during learning. It is crucial to the

selection of teaching methods, the arrangement of course content and the organization of the learning environment, which can directly affect the teaching quality. In the mid-nineteenth century, with the occurrence of the second industrial revolution, European countries began to promote mass education. How to teach became a real problem. In the past 200 years, many different learning theories have been proposed. These theories can be divided into three main philosophical frameworks: behaviorism, cognitivism and constructivism.

Ivan Pavlov observed that if dogs associate food with a bell, they will produce saliva when the bell rings even without food stimuli. Behaviorists believe that the form of learning is the same for humans. Behavior is the learner's response to environmental stimuli, and learning is the process to build connections between stimuli and responses. Behaviorist learning theory requires teachers to shape and correct students' behavior. For example, students can be trained to learn through rewards and punishments. Rewards increase the likelihood of certain behavior, and punishment reduces the likelihood.

Cognitive learning theory explores the learning laws by studying human cognitive processes. Cognitivists believe that a priori knowledge is a prerequisite for learning. Only when learners have enough prior knowledge can they understand the meaning of advanced topics and learn. Cognitivists view learning as an internal psychological process, including insight, information processing, memory and perception. Cognitivism goes beyond behaviorism but considers how human memory promotes learning. The human cognitive structure is composed of working memory and long-term memory, and the purpose of education is to store knowledge in long-term memory. Although the capacity of long-term memory is almost unlimited, the working memory capacity is very small. Therefore when learning new content, it must be ensured that the content is acceptable to the student's working memory and does not bring a lot of cognitive loads. When teaching the same course content, using different teaching materials will bring different cognitive loads and final learning results [4].

Constructivism was firstly proposed by Jean Piaget, and it emphasizes the importance of learners actively participating in the construction of knowledge. When acquiring new information, the learner needs to effectively combine the previous information with the new one to form an improved cognitive schema. Constructivists believe that teachers need to have a good understanding of what students already know before starting the class to arrange the teaching content reasonably. The design of the course should be based on the background knowledge of the students and develop with them. Teachers act as facilitators, encouraging students to construct their own knowledge system by answering open questions and solving real-world problems. It should be noted that constructivism is the most widely accepted learning theory in education today and has been identified as the most suitable one for online teaching [5].

Generally speaking, a high-quality online course should be based on multiple learning theories [6]. The behaviorism learning theory is mechanized and no longer suitable for the diversified needs of education nowadays. Therefore, we mainly referred to cognitivism and constructivism when designing the online course.

### C. Problem-based Learning

PBL is a teaching strategy in which real-world problems are used as the vehicle to facilitate the learning of knowledge as opposed to show concepts directly. PBL was originally designed to deal with criticism that traditional teaching methods cannot prepare students to solve real-world problems. The main assumption of PBL is that learning occurs when we solving real-world problems that we faced every day. When students study the course content, who cannot clearly express the purpose or intention of learning are rarely able to learn meaningfully. Problems provide them the purpose of learning. The PBL process is student-centered. Teachers are facilitators, not knowledge spreaders. PBL has been proven successful in multiple courses [7].

Some researchers applied the PBL method in their courses and obtained positive feedback. Reference [8] proposed an online teaching model based on PBL. Based on the results of the questionnaire survey, the authors found that students are very welcome to this teaching model and average scores even exceed those of traditional teaching in the past. A hybrid three-dimensional network teaching model based on PBL is proposed in [9]. The teaching practice proves that the application of this teaching model improves the enthusiasm and activity of students for learning and improves the teaching effect of online teaching, which is reasonable, feasible and effective.

## III. PEDAGOGICAL DESIGN

A PBL method was applied in the teaching process of the computer foundation course. The course was oriented to solve scientific computing problems and teach effective problem-solving methods. Through theoretical learning and experiments, we hope that students will be able to understand the basic concepts of computational thinking and master the ideas and methods of using computer science knowledge to solve problems. The process of solving problems includes describing scientific problems (abstract & model), formal descriptions of models, descriptions of models from the computer side (algorithms), implementation of algorithms, and analyzing the efficiencies of algorithms.

The quality of online teaching depends on the teachers' ability to apply a variety of online technologies and tools to reorganize teaching processes. It is necessary to comprehensively use tools such as LMS, live streaming platforms, social networking software, and online questionnaire or meetings to complete teaching management. In the online teaching process, teachers are not only the knowledge spreaders but also builders, leaders, promoters and facilitators in the learning community. In order to ensure the teaching quality, the teaching team enhanced interactions in multiple ways, strengthened teaching design based on learning theories and adjusted the teaching process based on students' behaviors, which formed a complete implementation of online teaching in the Spring 2020 semester.

### A. Teaching Procedures Design

We focused on the following procedures to conduct online teaching: (a) lead-in; (b) teaching resources; (c) self-directed learning; and (d) assessment.

#### 1) Lead-in

In the process of the "lead-in", we explained the teaching objectives and arrangements, introduced learning activities and educational resources, as well as emphasized learning

tasks and alternative ways to interact. At the beginning of the course, a period of “warm-up” and “ice-breaking” was needed for building a trusted learning community. There are two phases in the process of “lead-in”, teaching preparation and teaching implementation.



Fig. 1. Schedule of teaching preparation phase (February 1<sup>st</sup> to February 24<sup>th</sup>)



Fig. 2. Schedule of the teaching implementation phase (March 1<sup>st</sup> to April 4<sup>th</sup>)

In the teaching preparation process, teachers can understand the characteristics of the whole classes and individuals through an online communication group. Students can freely interact in the group with teachers, teaching assistants and other learners. Teachers were able to grasp the student’s previous learning status through questionnaires and the information provided by their counselors. Instructors should help students to familiar with the LMS, the Tencent classroom and the online judge (OJ) platform. LMS contains educational resources and a discussion forum. Tencent classroom is a live streaming platform and can also provide replay videos for users. It contains a chatroom that users can interact with others during the live. OJ platform can automatically evaluate the program that students submitted.

During this period, a study agreement could be established with students, and a self-check list should be published to them through the LMS and group announcements, as shown in Fig. 1.

The schedule of the teaching implementation phase shows in Fig. 2. Through continuous communication and adjustment in the early stage, students can gradually adapt to the online teaching model which is “self-study, reflection, interaction and feedback”.

2) Teaching Resources

Teaching resources include pre-recorded and live (or replay) videos, courseware and learners’ contributions.

a) Live videos

During a live broadcast, the contents on the slides were presented in a step-by-step manner, and teachers used annotation tools to mark and circle key points to ensure that students were clear about the current progress. After explaining a core concept, teachers could ask the question “Is the explanation clear? Please type 0 or 1 in the chatroom.” Then, they could quickly get feedback from the students and made adjustments to the teaching process as necessary. Instructors encourage students to speak in the chatroom if they have any questions and pay attention to the chatroom during the live broadcast. It is an effective method to reduce the sense of loneliness of students through online interactions and to ensure the quality of education.

b) Replay videos containing teacher-student and student-student interactions records

During a live broadcast, the teacher-student and student-student interactions were recorded, together with the teaching process to generate the replay. This allows students to not only review the content of the course but also reproduce the interaction process. On the one hand, some students may be shy and not good at answering teachers’ questions or asking their own questions. Therefore, the replay videos containing interactions records do provide incentives for those students through the process of “seeing or listening” to others to answer or ask questions. The “alternative interaction process” is also an important part of the course. On the other hand, if students miss some important content or do not have enough time to think about the questions proposed by teachers, they can review the replay videos to have a more comprehensive understanding of the course content.

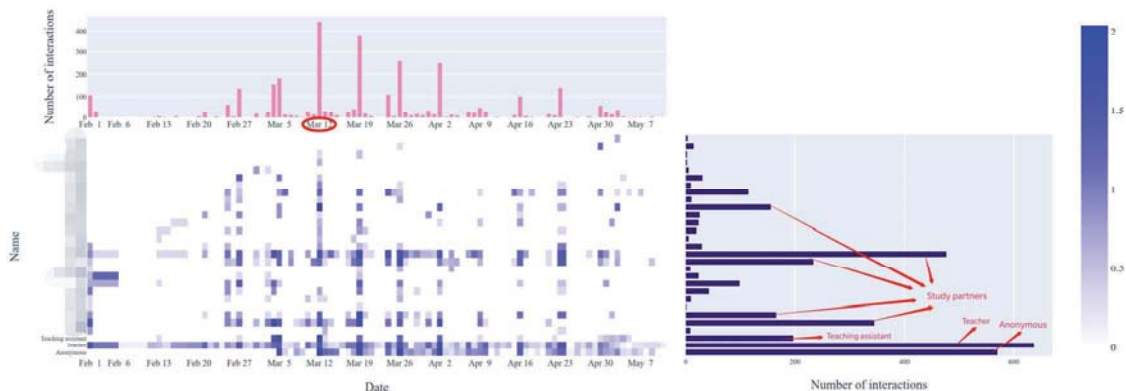


Fig. 3. Daily interactions of class 197717 in online communication group (February 1<sup>st</sup> to May 7<sup>th</sup>)

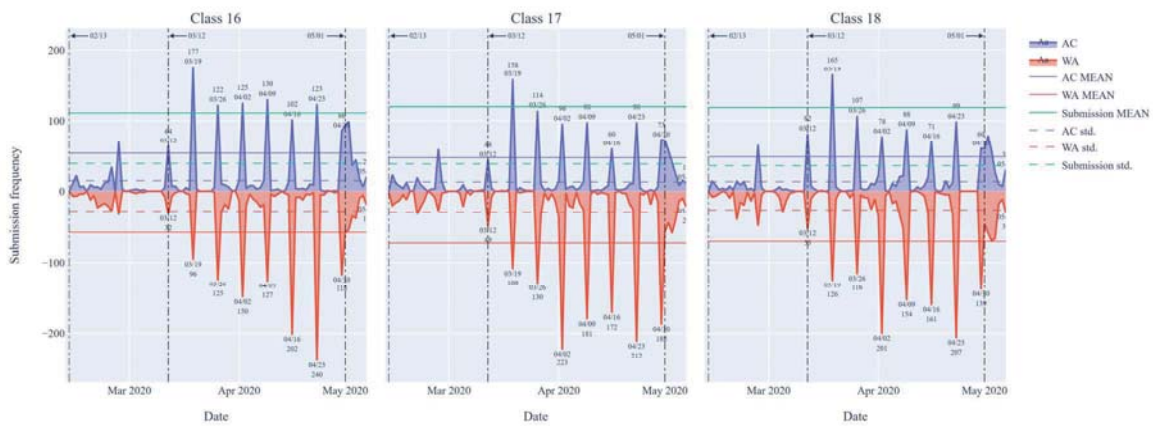


Fig. 4. Daily submissions on OJ platform (February 13<sup>th</sup> to May 7<sup>th</sup>)

### c) Resources that incorporate learners' contributions and ideas

The teaching improvements are usually based on the feedback from each iteration. Although teachers tried to decompose the knowledge from the perspective of the beginners, contributions and ideas generated by learners still need to be considered. Explaining and expanding the contents that were learned from students' study experiences can be applied as a useful supplement. The teaching assistant organized a live broadcast to explain the problems about basic grammar on April 5<sup>th</sup>, with the students providing good feedback. Meanwhile, teachers watched the live broadcast held by the teaching assistant, which could effectively assist them in teaching reflection.

### 3) Self-directed Learning

Students' self-directed learning activities include watching pre-recorded and live (or replay) videos, learning extracurricular resources, participating in synchronous discussions in the online communication group and live broadcast chatroom, as well as asynchronous discussions in the discussion forum. Relying on instant messaging tools, teachers can provide timely feedback to the questioners. This enables students to get answers more quickly and acquire a sense of accomplishment.

The activities in the online communication group of class 197717 from February 1<sup>st</sup> when the group was established to May 7<sup>th</sup> was shown in Fig. 3. The group includes three classes 197716, 197717, and 197718, so the number of interactions of the teacher and the anonymous are counted as one-third. Many students tended to interact with others anonymously, even when answering peers' questions, in which way the shy students may feel more comfortable. Through the establishment of a trusted learning community, more and more students were transformed into study partners and they began to help each other and cooperate to solve problems. Teachers gradually changed from builders and controllers to facilitators and promoters.

During discussions in live broadcast and online communication group, students might not have had enough time to think about their answers before responding. The online discussion forum provided in the LMS is an extension of teaching practices, which enables students to carefully analyze the problems and think more deeply about their answers. This approach provides opportunities for students to identify, research and reflect before responding.

### 4) Assessment

The OJ platform enables students to practice and get feedback instantly. Meanwhile, it can help the teachers to conduct teaching inspections and adjust the teaching arrangement according to the feedback. In order to better adapt to the self-learning of students at different levels, and to understand the basic situation of the class of 2019, the winter vacation warm-up competition opened on February 13<sup>th</sup>. From March 12<sup>th</sup>, unit practice competitions would be held every Thursday. The duration of the competitions is usually three hours, and after competitions, students can further complete the practices from the question bank. During May Day, "basic practice exercises" and "thinking trials" were offered for students with different learning requirements.

The daily submissions on the OJ platform of the three classes are shown in Fig. 4. The blue area represents the number of correct submissions (accept, AC) per day, while the red represents the number of wrong submissions (wrong answer, WA). As shown in the figure, there would be a peak in each Thursday when the competition was held. The May Day exercises were released on May 1<sup>st</sup>. The variance of the submission frequency of the three classes is not large, indicating that there is no significant difference in the practice of students in different classes. Through the analysis of statistical data, teachers can understand the overall situation of practicing, and conduct teaching adjustments correspondingly.

### B. Strengthen Online Teaching Design Based on Learning Theories

Relying on the constructivist learning theory, teachers should encourage students to cooperate and interact with their peers, so that students can process information and construct their own understanding of the knowledge. On the one hand, teachers need to pay attention to design multi-dimensional teaching scenarios to facilitate effective learning. They should also seek to develop students' abilities to find innovative solutions and resolve problems. On the other hand, teachers need to be aware of cognitive difficulties in the entire learning process. Situational cognition theory regards both the goal and process as a whole concept. Therefore, students' misunderstandings of information presented during the learning process are still parts of the construction process. These contribute to the understanding of complete knowledge.

#### 1) Multi-dimensional teaching scenarios design

The Fibonacci sequence was taken as an example to describe the design of the teaching scenarios, as shown in TABLE I. Through the multi-dimensional teaching scenarios (live broadcast, online communication group, discussion forum and Experiments), the Fibonacci sequence was utilized throughout each chapter of this course, including abstraction, modeling, data description, program implementation, and algorithm efficiency analysis. Students could master the core concepts of the course gradually by constructing their own knowledge in different teaching scenarios.

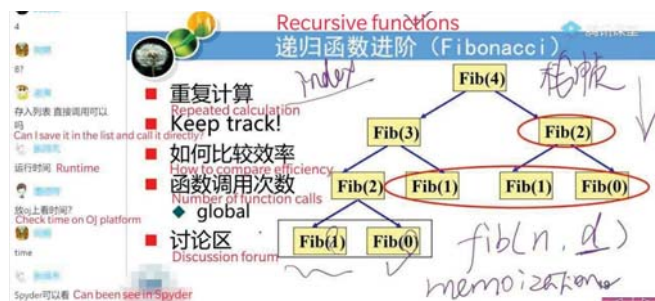


Fig. 5. In the live broadcast on April 7<sup>th</sup>, the teacher guided students on how to improve the computing process

The example demonstrates that the design of multi-dimensional teaching scenarios is effective. Through gradually deepening the explanation of the problem in various teaching scenarios, this will help students to process information and implement an active construction of knowledge. From active discussions in the online communication groups and the discussion forum, we found that the students were guided by the teacher at the beginning, and then they were able to solve problems by themselves.



Fig. 6. The in-class quiz

TABLE I. TEACHING SCENARIOS DESIGN (TAKING FIBONACCI SEQUENCE AS AN EXAMPLE)

| Date   | Scene                                   | Teaching Design   |
|--|---|---|
| March 10 <sup>th</sup>                                     | Live broadcast                          | The teacher explained the Fibonacci sequence mathematical model utilizing induction, and focus on guiding students on how to abstract the problem and modeling.   |
| March 17 <sup>th</sup> /24 <sup>th</sup> /31 <sup>th</sup> | Live broadcast discussion               | The teacher introduced the basic syntax of Python, including simple data types, lexical and control statements. After the introduction of the function definition and function call, the recursive function was explained using the factorial as an example. The recursive and non-recursive solutions of the Fibonacci sequence were released as an extension of the live broadcast to the discussion forum in the LMS.  |
| April 7 <sup>th</sup>                                      | live broadcast discussion               | The teacher introduced the knowledge of recursive functions, as shown in Fig. 5. Teacher guided students to keep tracking the recursive calling process to find the repeated calculations. Then improve calculation efficiency using the memorization method and elaborated how to use the timer module for statistics, and use a global variable to count how many times the function had been called. The discussion forum was also used as the extension of the teaching contents in the live broadcast. |
| April 14 <sup>th</sup>                                     | Live broadcast                          | Practicing in the class help students understand how to construct recursive programs through examples, and clarify the internal implementation of recursive function calls.   |
| April 15 <sup>th</sup>                                     | Online communication group              | Students raised questions about the “memorization” method in their practice and doubted how to measure running time. They discussed the question in the online communication group.   |
| April 23 <sup>rd</sup>                                     | Experiment & Online communication group | In the experiment, the example of evaluating time-consuming triggered students to think about how to reduce the running time of programs.   |
| April 28 <sup>th</sup>                                     | Live broadcast                          | The teacher introduced how to statistic the running time of programs. When evaluating the complexity of the algorithm, compared the time and space complexity of the recursive and non-recursive solution of the Fibonacci sequence. Combined with the discussion on April 23 <sup>rd</sup> , the teacher explained the Python built-in data type and the time complexity of dictionary related operations, which confirm the live broadcast on April 7 <sup>th</sup> .                                     |

## 2) Pay attention to the contribution of wrong cognition in the learning process

Each live broadcast sustained 1.5 hours, and it is important to increase students’ participation in the class. On the one hand, in-class quizzes help to check the understanding of students and whether they have mastered the key points. Besides, by adding error-prone options and inviting students to analyze the question, teachers can quickly correct the misunderstanding and become effective facilitators. Ultimately, teachers can have a positive contribution to the

construction and development of complete knowledge. The interactions between teachers and students usually helped the students to correct their answers.

A quiz that was presented in a live broadcast on March 31<sup>th</sup> as shown in Fig. 6. The correct answer was ‘A’, and some confusing options ‘B’, ‘C’ and ‘D’ were added. Only nine students gave the right answer, with one student revising the answer in the chatroom. Through the discussion in the live broadcast, students were able to identify the correct answers during the teacher’s explanation.

#### IV. BEHAVIOR-BASED TEACHING ADJUSTMENT

##### A. Correlation analysis

Usually, the LMS and online tools can collect the student's learning behavior, which helps teachers to identify problems early and make improvements and adjustments as necessary.

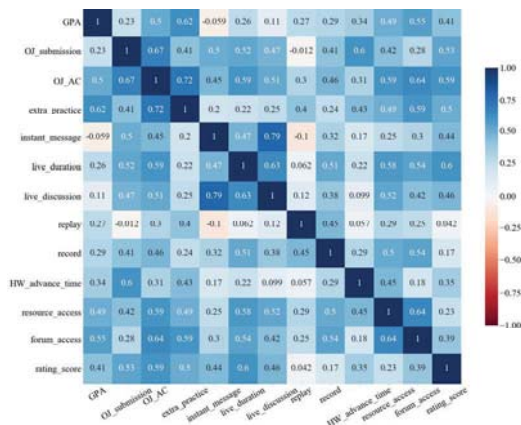


Fig. 7. The correlation coefficient between indicators

Through correlation analysis, teachers can find indicators that are highly related to learning performance and conduct teaching adjustment. The matrix of the correlation coefficient is shown in Fig. 7. There are 13 indicators totally, and the descriptions are as follows.

- GPA: Students' grade point average in the first semester

- OJ\_submission: Number of submissions on the OJ platform
- OJ\_AC: Number of correct submissions on the OJ platform
- Extra\_practice: Number of extra problems students practiced on the OJ platform
- Instant\_message: Number of times students spoke in the online communication group
- Live\_duration: Duration of participating in the live broadcast
- Live\_discussion: Number of times students spoke during the live broadcast
- Replay: Completion ratio of replay videos
- Record: Completion ratio of pre-recorded videos
- HW\_advance\_time: Number of days before the deadline when students submitted homework
- Resource\_access: Number of times to download teaching resources on the LMS
- Forum\_access: Number of times to access the discussion forum on the LMS, including creating, replying and reading posts
- Score: Students' mid-term test scores

Most of the indicators are correlated to test scores except "replay", "record" and "resource\_access".

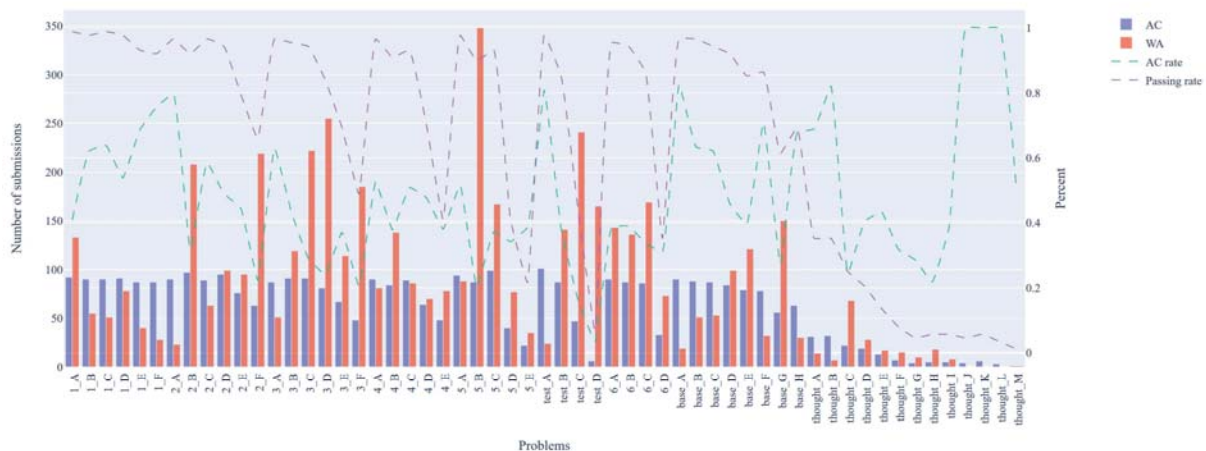


Fig. 8. Correct rate and passing rate of problems on the OJ platform

##### B. Teaching adjustment

Teachers can improve and adjust the teaching process based on the correlation analysis. Indicators that are correlated to learning results are more important for them to pay attention to and facilitate students to complete learning tasks. The indicators related to the OJ platform "OJ\_submission", "OJ\_AC" and "extra\_practice" are all moderate positive related to test scores. Students who practice more actively on the OJ platform may obtain better results. Teachers can send reminders to burnout students and encourage them to practice on the OJ platform. The correct rate and passing rate of each problem shown in Fig. 8.

Teachers can identify the difficulty of each problem and explain the corresponding knowledge in live broadcasts.

In the online environment, it is easy for teachers to lose students without knowing. Therefore, interactions become the most important approach for them to understand the learning status of students. It is important to identify active participants, divers, and non-participants through students' interactive activities. We provide multiple ways for students to interact with teachers and other learners. The indicators "instant\_message", "live\_discussion" and "forum\_access" refer to the number of interactions in the online communication group, chatroom of live broadcast and discussion forum respectively. These indicators are all related

to the scores. This means that teachers should facilitate students to interact with others actively by praising active

participation, encouraging divers, and reminding non-participating students.

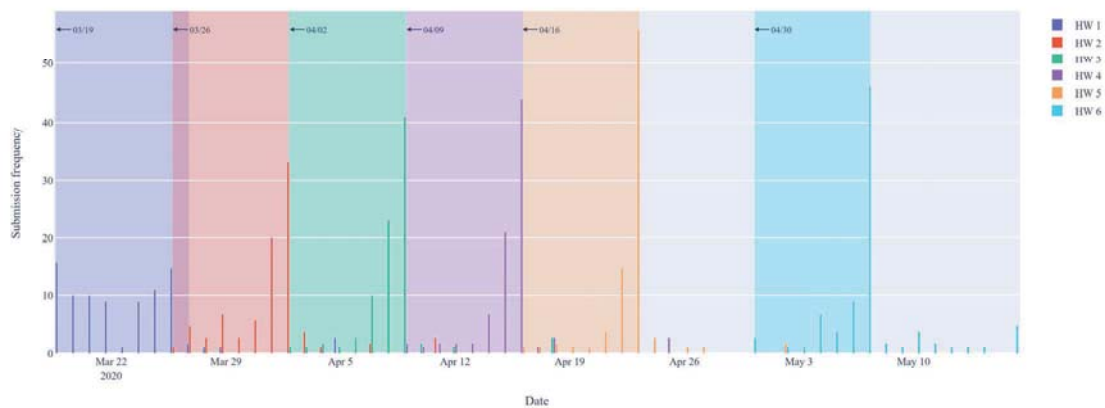


Fig. 9. Number of daily submissions of homework

The indicator “HW\_advance\_time” reflects the learning habit of students. It is moderate related to test scores. Students who submit homework earlier may achieve better performance. The statistics of the submission frequency of the homework shows in Fig. 9. Each color block represents the duration that students can submit homework. We can see that as the course progresses and the difficulty of homework increases, learners are prone to burnout. Teachers need to send reminders and facilitate them to complete the learning tasks.

## V. CONCLUSIONS

After the practice of online teaching for nearly a semester, we found that it is different from traditional teaching methods. In online teaching, teachers need to design the content of the course more carefully, such as whether the sequence of knowledge points is reasonable and whether it is easy to understand for students. Different knowledge needs to be presented in different ways. Designing based on the constructivism learning theory is a widely recognized way in the education field.

In online teaching, teachers cannot get feedback directly, and can only rely on indirect methods, such as asking students if they have any questions during a live broadcast. The interaction between students and teachers can only be carried out through online communication groups and discussion forums. Therefore, interaction is very important to ensure the quality of online teaching. It is a possible way to provide students with synchronous and asynchronous interactions in the course. When students have problems that need immediate feedback, they can communicate synchronously. When they want to discuss some difficult problems in-depth, they can use asynchronous communication. Teachers should encourage students to socialize, and the analysis results show that the number of speeches made by students in online communication groups, discussion areas and live broadcasts is related to their final performance.

At the same time, utilizing various digital tools is also very important for teachers to manage the learning process efficiently. For example, LMS is used to manage teaching resources, while the OJ platform is used to automatically evaluate the code submitted by students. These tools can make it easier for students to train themselves and master

knowledge. The results of correlation analysis show that students’ activities on these platforms are related to their final performance.

Teaching adjustment is a very important part. In traditional teaching, teachers will also adjust teaching, but most of them are based on the intuitive feedback of students. In an online environment, teaching adjustments can be made based on student behavior data. For example, through the submission records of students on the OJ platform, the correct rate and pass rate of each question can be calculated. For some difficult questions, teachers can consolidate relevant knowledge points in the classroom. By counting the submission records of students on the OJ platform and the records of submitting homework on the LMS, it is possible for instructors to facilitate and promote students to complete tasks on time when they are relatively tired.

This paper describes how to transform traditional courses into online courses, and explores the relevance of some students’ behaviors to their final performance to make corresponding teaching adjustments. In online education, we can obtain students’ behavior data, which is very valuable. In future work, we will continue to explore how to make full use of these data to improve the efficiency and effectiveness of teaching.

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