



Teaching of Human Parasitology During the COVID-19 Pandemic in China

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Since the coronavirus disease 2019 (COVID-19) pandemic, human parasitology education has been exceedingly disrupted. To deliver human parasitology knowledge, medical universities in China have employed multiple measures, some of which have had positive outcomes that have not yet been summarized. The objective of this review is to share the Chinese experience as the human parasitology teaching methods were transformed. In general, we adopted a fully online teaching model under urgent pandemic control measures based on a well-structured teaching model that integrated the course preview, live lecture, review, and assessment. Combinations were attempted of COVID-19 and parasitology teaching contents. Some active learning models, such as case-based e-learning and flipped classrooms, were proposed for offline and online blended teaching during the normalization stage of the pandemic. Meanwhile, we discuss both the strengths and flaws of online and blended teaching. Some useful assessment tools are presented for reference purposes. In conclusion, this transition to online and online-offline blended human parasitology teaching in China has boosted innovative teaching activities and may continue to catalyze the transformation of medical education.

Keywords: China, COVID-19, human parasitology, teaching model, e-learning, medical education

INTRODUCTION

Coronavirus disease 2019 (COVID-19), which suddenly struck China in December 2019, has spread worldwide (Centers for Disease Control Prevention, 2021a). Such a severe pandemic has challenged all aspects of society – factories were shut down, transportation was limited, and all on-campus activities were postponed (Sharifi and Khavarian-Garmsir, 2020).

However, this global health crisis offered opportunities to accelerate the current transformation of higher education. China's authoritarian regime launched the slogan, “suspend classes without suspending learning” (Ministry of Education in China, 2020), which required institutions to perform remote online teaching to comply with the nationwide home-based quarantine strategy.

Abbreviations: COVID-19, coronavirus disease 2019; MOOCs, massive open online courses; CBEL, case based e-learning; FC, flipped classroom; BOPPS, Bridge-in, Objective, Participatory learning, Post-assessment, and Summary; SERU, student experience in the research university.

As a significant branch of medical sciences, human parasitology is a compulsory course for the undergraduate major in clinical medicine and includes knowledge of the parasites that affect humans and important host–parasite relationships. Because of the urgent need to secure the educational continuity of human parasitology under the COVID-19 outbreak, the human parasitology teaching model in China has undergone an unprecedented change from traditional face-to-face teaching to initially an online model and subsequently a new hybrid one. Students encountered many difficulties during online teaching, such as a decrease in motivation, feelings of loneliness, technical problems, and decreased interaction with teachers and other students (Lorenzo-Lledó et al., 2021). The teaching staff also reported unfamiliarity with remote teaching. This paper introduces various teaching methods and tools to solve these difficulties, and we share our reflections regarding the innovations in human parasitology teaching during the outbreak in China.

ONLINE TEACHING OF HUMAN PARASITOLOGY DURING THE EMERGENT STAGE OF COVID-19

At the beginning of the pandemic, one of the vital characteristics was that neither the staff nor the students were prepared for absolute web-based education. Online teaching had previously complemented face-to-face teaching, but it then began to dominate education. This model made it possible to deliver knowledge to massive crowds without the threat of human-to-human disease transmission. Meanwhile, the geographical barriers and temporal spaces, which contributed to large-scale information broadcasting.

Many efforts were made to ensure the success of remote human parasitology teaching. For instance, specific training programs for computer skills and software were set up for teachers to enhance their familiarity with devices. Lectures on online teaching techniques were given for the same goal. For students, considering their constant exposure to digital devices, some student-aimed brochures about the platform usage were adequate. Moreover, some departments required rehearsals before formal classes to test the environment and internet connections with students. To ensure educational equity, for students with family poverty, universities established funding sources to cover the network expenses caused by online learning.

The human parasitology course in China is composed of theoretical lectures and experimental practice (Zhao et al., 2012). For the lectures, the goals for undergraduate students are as follows: first, comprehending the morphological features, life cycles, and pathogenesis of primary parasites; second, understanding the pathogenic mechanisms of parasite-related diseases; and third, knowing about the diagnosis, treatment, prevention, and control of parasitic infections (Zhao et al., 2012). As a result, a well-structured model was developed to satisfy these requirements in human parasitology teaching during the COVID-19 pandemic (**Figure 1**). This model consisted of four parts: preview, live lecture, review, and assessment. The key

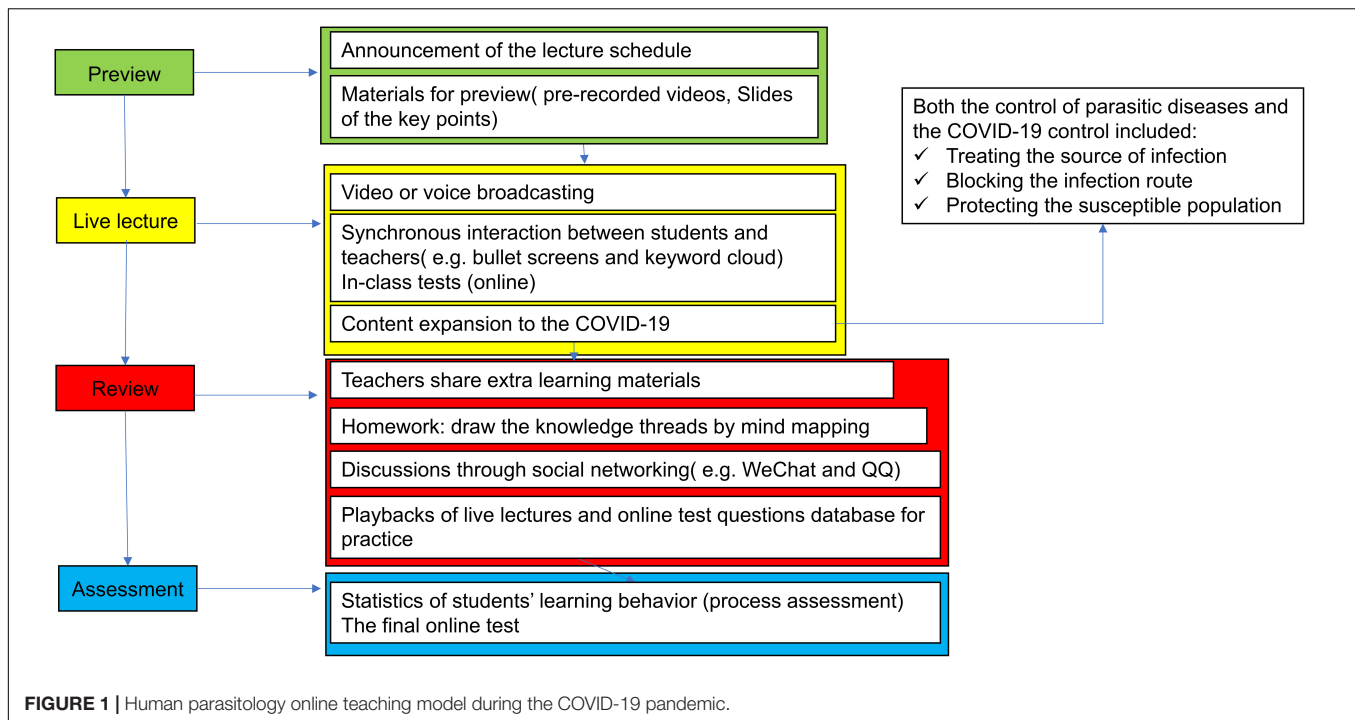
elements in the process and some useful teaching tools were listed in the framework to aid teachers in their pedagogical practices.

In the preview, students were offered the key points of the course and some learning videos. The findings of previous studies have shown that through videos, students gain a more effective learning experience, and videos provide a powerful mechanism for instructors to facilitate various multimedia learning principles (Oakley and Sejnowski, 2019). Prerecorded videos could be downloaded for massive open online courses (MOOCs). Nevertheless, the preview video length should be restricted to 20 min, as long sessions decrease students' interest. Apart from the length, during the preview, teachers are encouraged to issue a few questions via the platform. Students can choose either to write their thoughts in the comments area or to keep these questions in mind and learn the answers later in class.

The live lectures integrated multiple models that received positive anecdotal feedback from participants. The application (i.e., Rain Classroom, a new smart solution for online live teaching jointly developed by Tsinghua University and Xuetang Company in China) allowed the real-time sharing of PowerPoint and voice/video broadcasting. More importantly, students could post bullet screens at any time to interact with their professors. These bullet screens could be seen by classmates, and the screens could be collected and analyzed by the background database. Afterward, a “keyword cloud” was presented according to the appearance of different words that the program (i.e., Wordle) captured, which is also called data visualization. In a survey, data visualization was found to be a useful tool: student grades were higher after data visualization was implemented and a questionnaire indicated 93.75% positive feedback (Vega-Garzón et al., 2021). In combination with online quizzes, the impact of data visualization is maximized. The accuracy rates of the whole class along with the proportion of the accuracy rates for each selected option can be shown on slides that enable learners to monitor their progress and recognize weaknesses in certain knowledge areas (Jabbar et al., 2016). Furthermore, a backup plan was always in place in case of a platform breakdown or connectivity problems. Other audiovisual conferencing software platforms such as Tencent QQ, Ding Talk, and Zoom (mainly for international students) were constantly considered substitutes.

Additionally, the teaching content could be enriched with some COVID-19 studies related to parasitology. For example, during the interdisciplinary session with immunology, instructors introduced the way intracellular pathogen SARS-CoV-2 interacts with receptors located on the surface of mammalian cells, a method that is also used by prokaryotic and eukaryotic microorganisms (de Souza, 2020). The control of parasitic diseases was linked to COVID-19 control, as both measures include treating the source of infection, blocking the infection route, and protecting the susceptible population. Such teaching methods aroused students' interest in parasitology and cultivated their One Health awareness (Sinclair, 2019).

The instructors were advised to attach extra learning materials to the platform after live teaching, including links to external online resources and open questions. For example, regarding *Plasmodium*, related research articles and reference books about



mainstream prevention measures could be listed to prompt self-directed study by the students. The students were encouraged to draw knowledge threads by mind-mapping to summarize the content of certain parasites. Discussions between the teachers and students were available through social networking (e.g., WeChat and QQ). To some extent, the social application broke the boundary of conventional classroom teaching, in which the students often felt stressed during discussions, and helped to create a multicenter debate model for convenient interactions between students and teachers. In this model, more students could participate in the debate synchronously without disturbing one another, and some introverted students were more willing to express their opinions by posting in the chat room. Some creative ideas were introduced to our practical teaching under this model. The students assigned nicknames to common parasites based on the features. For example, *Entamoeba histolytica* was called “the culprit for flask ulcer,” and *filaria* was named “the silk net that blocks the lymphatic vessel.” This naming game made studying more enjoyable, and the teachers applied these interesting topics to the human parasitology MOOCs, which was welcomed by the students.

Another positive feature about the online education platforms was the unlimited playback feature for live lectures, allowing absent students to catch up and others to review. The platform also provided an online test question database for students to review their learning outcomes and automatically adjust their self-learning plan.

With regard to practical lessons, the faculty adopted a method combining online lecture and virtual laboratory to provide students with valuable scientific learning experiences when in-person learning was not possible (Delgado et al.,

2021). In this section, students were required to observe the morphological features of select parasites and conduct practical operations concerned with immunological and molecular biology technologies (Zhao et al., 2012). The theoretical parts of the experiment were illustrated via Rain Classroom. For instance, some pathological sections of high definition were posted to the platform, where the students could magnify the picture for details while listening to the teachers' interpretation. Later, the students' drawings of these sections were delivered to the teachers online. Furthermore, with the assistance of universities' e-library resources, the students had free access to a variety of websites ranging from The Journal of Visualized Experiments to Springer Protocols. Although hands-on experiments could not be performed during remote teaching, the university's virtual and national simulation experimental teaching center provided students with experience from more intuitive, microscopic, and personal perspectives. Some experiments, such as the circumoval precipitin test, which used to be difficult for students to enroll in, can now be carried out repeatedly via multimedia methods (e.g., animation and interactive games). With these tools, the instructor taught the students lab theory, scientific methodology, data analysis, and critical thinking skills to overcome scientific obstacles (Delgado et al., 2021).

Given the lockdown, offline examination papers were no longer suitable for student evaluations. Instead, a more procedure-centered and diversified assessment system was implemented. The system consisted of a process assessment (40%), in-class tests (5%), homework (15%), and an online final exam (40%). In contrast to traditional test papers, the clinical case analyses took the online final test more into account, and the proportion of multiple-choice questions was increased.

Since invigilation was hard to achieve when the students were behind a remote computer screen, the sequence of questions was randomized for individuals, and the number of questions was doubled while the timing remained the same. Before the grades were released, the students evaluated and commented on the human parasitology subject (Liu et al., 2018). In addition, student attendance, class duration, and other statistics related to students' learning behaviors were available to the teachers. Based on these intelligent analyses of the entire class, the teachers made adjustments for the future courses.

ONLINE-OFFLINE BLENDED TEACHING OF HUMAN PARASITOLOGY DURING THE NORMALIZATION STAGE OF COVID-19

Because the SARS-CoV-2 spread was successfully controlled in China, the management of the COVID-19 pandemic entered a normalization phase. Students with negative results in the detection of SARS-CoV-2 were permitted to return to school. Although universities in high-risk regions implemented an isolation policy to protect students from external infection, students and staff returned to face-to-face teaching after a 2-week self-quarantine in the dormitory.

With the experience of full online teaching, the universities developed a blended methodology (online-offline blended teaching). The blended method took advantage of the software's recording and polling functions, which were highly appreciated by the students in the classroom, and many of the students claimed that they were better able to concentrate on the course. In addition to serving as a regular teaching model, the digital platform was used in the modified case-based e-learning (CBEL) model and flipped classroom (FC) (Sawras et al., 2020).

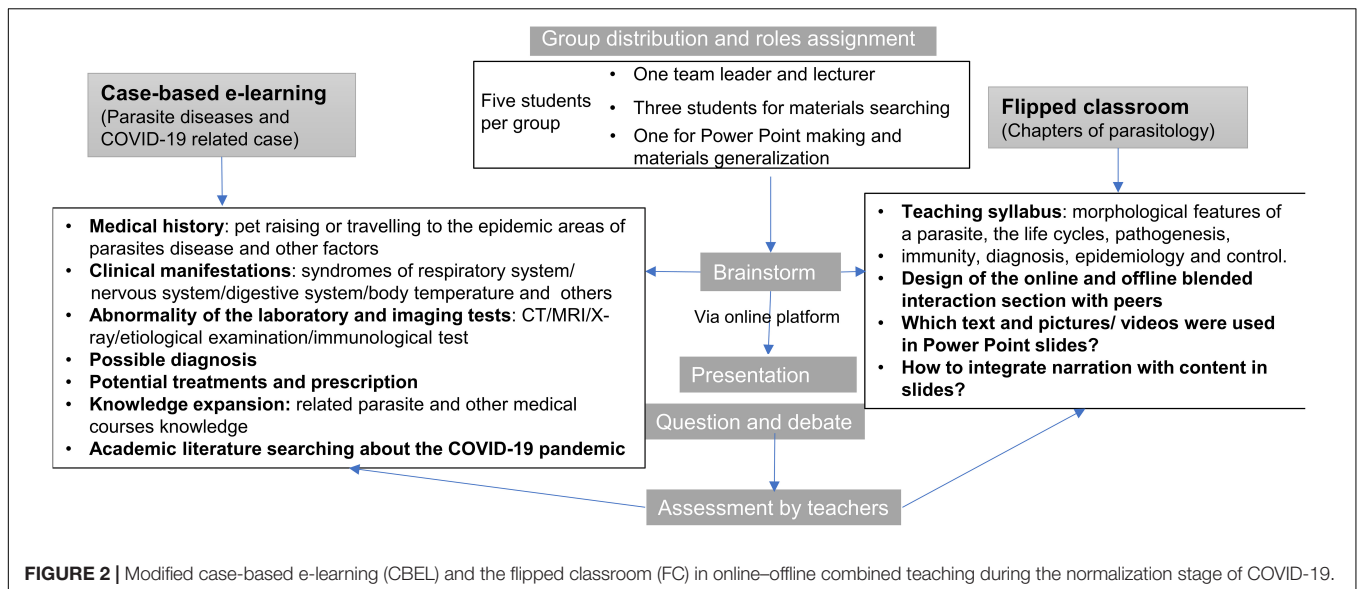
The online-offline blended teaching method of human parasitology was derived from the modified Bridge-in, Objective, Participatory learning, Post-assessment, and Summary (BOPPS) model (Wang et al., 2021). This model divided the teaching activity into multiple pieces to better explain the framework of blended teaching pedagogies. The bridge-in was the introduction to the human parasitology course, and the objective was the learning goal, both of which were achieved through offline teaching. Participation was reflected in the CBEL and FC patterns (Figure 2), which highlighted self-directed learning, from which the students should be able to ultimately assess and summarize the lesson.

In the modified CBEL, parasite-related clinical cases were shared on the digital platform. The chosen cases should be openly discussed, close to daily life, and combined with current affairs (COVID-19). For example, we designed a case in which an expectant mother was infected with *Toxoplasma gondii* because she raised cats but also had close contact with confirmed COVID-19 patients (Khedmat et al., 2021). In a sense, this creative combination required a more comprehensive understanding of this parasite. Considering that the students could not find COVID-19 knowledge in the textbook, they were

forced to research newly published academic literature and make connections to the case. The students were distributed into small groups for discussion. As they brainstormed, the students could post some materials they found into their group chats for others to refer to and analyze the case from multiple aspects. Generally speaking, the brainstorming usually focused on the medical history, clinical manifestations, and abnormality of the laboratory and imaging tests to provide possible diagnosis and treatment (Figure 2). After the offline group meetings, new findings were exchanged on the platform, which the members could check at their convenience or discuss further without gathering in person. The teachers could also use this platform to monitor the preparation procedure and evaluate personal performance. For some students who were not physically present at the university, video conferencing software was highly recommended. In the reporting stage, both the teachers and other groups were encouraged to raise doubts and questions, and the presenters had to defend their positions with their background knowledge and previous research results. After the presentations, the students had to submit their summary reports online. At last, the teacher assessed individual performances and helped the students integrate their learning outcomes into clinical practice.

The whole CBEL model was a student-centered framework (David, 2017). The framework integrated different curricula, such as human parasitology, clinical diagnostics, pharmacology, physiology, and psychology. Throughout this learning, participant collaborations were enhanced. After they analyzed clinical cases, students were supposed to independently discover questions sentence by sentence. In this active-learning setting, students improved their problem-solving and critical thinking skills as well as their interactivity (David, 2017). Each group member played different roles in the scenarios, which gave students the freedom to develop their personal interests. Moreover, the application of digital devices and resources provided the participants with convenience and efficiency, making the project more interactive.

In the FC pattern, the process by which students self-taught and prepared their presentations was similar to the active learning setting in CBEL. For example, a few chapters of parasitology were taught by the students. They were asked to design teaching plans and make PowerPoints that would be peer-reviewed by classmates. The teachers recorded the students' lectures on the digital platform and commented on their performance (Figure 2). These teaching tools were encouraged so the students could gain more experience. As a reversal of traditional teaching, the FC facilitates the active learning required in student-centered tasks to acquire knowledge (Jabbar et al., 2016). It can also be a tool to measure students' basic learning outcomes of parasitology and their knowledge system of medicine. However, according to a previous survey, students in the FC reported more burden and pressure than did those in lecture-based methods (Tang et al., 2017). The timing of the FC needs to be controlled, and the proper guidance of tutors is advised to lessen students' burden. Both the CBEL and FC models were modified based on the instructors' experience in full online teaching, which was a good sign for the long-term development of human parasitology education.



Our retrospective transformation of human parasitology teaching led to certain advancements. The online and online–offline hybrid models integrated several new pedagogies, including the student-centered concept, active learning, and the BOPPS model. These pedagogies permitted human parasitology teaching to be completely transformed along with its theoretical bases, grounding the innovation. The joint use of these pedagogies increased the emotional bond between teachers and students and the course interactivity, both of which caused some students to be more interested in human parasitology and to possibly take it as their future major. Meanwhile, both the online and blended methods created a learning community for students. The leading role that teachers played in traditional teaching was replaced by the students' group learning. The learners could communicate with each other via the platform and create an active atmosphere while the teachers supervised the procedure and offered supplementary guidance. Thus, not only did the students benefit from the community, but the teachers also reported more connection and achievability (Roussel et al., 2020).

ASSESSMENT OF THE TRANSFORMATION OF THE HUMAN PARASITOLGY TEACHING MODEL DURING THE COVID-19 CRISIS

The learning objectives of human parasitology have undergone some changes during the COVID-19 pandemic. In the traditional offline teaching and the beginning stage of online education, one learning objective was to build a clear view for students that parasitic disease were still heavy burdens for public health systems globally. Another learning objective was to help students understand the basic knowledge of commonly seen parasitic disease including the prevalence of parasitic disease and the main

principles for parasitic disease control and treatment. However, integrations between the parasitic disease and the COVID-19 pandemic knowledge were tried both in the online teaching and blended teaching of human parasitology. Therefore, the focus of learning objectives for this course has expanded to its relation to global health emergencies (COVID-19 pandemic) and the main principles for infectious disease treatment to cultivate a global view on public health for students.

COVID-19 sped the integration of educational theories in human parasitology teaching assisted by new technologies. A majority of the digital platforms were equipped with blockchain, big data, data visualization, and virtual reality technologies. Blockchain is being used to build new interventions to improve the prevailing ways of sharing, delivering, and securing knowledge data among universities and to maintain personal learning records (Raimundo and Rosário, 2021). Big data are applied to analyze students' learning behavior. Overall, digital technologies are likely to be further integrated into higher education after the epidemic.

With advanced pedagogies and technologies, the reformation of human parasitology teaching in China throughout the COVID-19 situation has shown great practical value. In a published evaluation of online synchronous clinical training during the COVID-19 pandemic, students particularly enjoyed keeping in contact with peers and tutors when offline learning activities were canceled (Junod Perron et al., 2020). With higher perceived ease of use and usefulness of online education, students will have stronger motivations to switch from offline to online learning platforms (Jin et al., 2021). In this context, online courses also boosted their motivation to learn and created a student-centered learning community. With the application of virtual laboratories in online education, there was less need for technician presence which helps to save more human resources, time, and expenses. The use of experimental animals was also reduced which satisfied the 3R principles- replacement, reduction and refinement. The virtual laboratories were proved

to minimize instructor dependency, which was of importance for students to develop practical skills (Radhamani et al., 2021). In a qualitative assessment of an online laboratory experiment among students, of the 8 categories about quality of course procedures, 6 had mostly positive feedbacks while two were mostly negative (King et al., 2021). For the online-offline hybrid models, owing to the convenience that digital devices provided, students got more involved in the class, and the student-centered framework was able to be fulfilled easily. The experience from early full online teaching has ensured the rapid adaptation into new CBEL and FC models for both teachers and students.

We have received some positive feedback from students. For example, a student from clinical medicine said that online human parasitology teaching provided more learning freedom, and the preview was supervised via a digital platform which helped her to understand the key knowledge like the life cycle and morphological features of parasites. Another international student claimed that the online teaching of human parasitology was able to track down his learning process which enhanced his self-discipline in studying, and the virtual laboratory section was very intriguing where the incorrect operations were indicated and rectified automatically.

However, this model has some limitations. It cannot fulfill the requirements for research-based studies for postgraduates. The platforms need to be improved to accommodate the high volumes of students and the large scale of remote learning experienced during the pandemic, meaning the domestic infrastructure must be improved of the internet and communication. In the future, perhaps the problems will be solved with more advanced technology or design. What's more, students still had a sense of isolation during online education which couldn't be fully erased by social networking interaction (e.g., WeChat and QQ). Based on an interview survey of college students, the COVID-19 pandemic may cause several psychological disorders including sleep deficiencies, depression, anxiety, and even post-traumatic stress disorder in the student group (Salari et al., 2020). These may relate to academic stresses and the loss of social contact with both classmates and teachers in online teaching. With regard to online-offline blended teaching, CBEL and FC patterns made up for the losses of social contact, but the efforts to learn how to play leading roles via a digital platform in class may load more extra burdens for students. And students got distracted easily by digital devices and the CBEL, as well as FC models, restrained the number of students involved in the class (usually under 15) which increased the burden on human resources and teaching fields. In online-offline hybrid models, students' enthusiasm and participation in the CBEL and FC models were closely related to their personalities and levels of experience (Chen et al., 2022). For online experiment education, an authentic learning experience of hands-on experiments was indispensable for laboratory skill training, and students will still require this exposure which can be achieved through offline classes. Apart from that, the losses of recording actual data that students got from their hands-on tests for analysis may decrease their interest to explore parasitology experiments.

Additionally, this unusual transition that the COVID-19 pandemic caused has raised higher command of the present students' performance system. The proportion of process evaluation in final grades was added to online education. But in the CBEL and FC models, the learning effectiveness became rather diverse so that the grades given by only teachers may not fully reflect students' actual performance. To complement this flaw, the student experience in the research university (SERU) survey could be added in the future which adopted a retrospective pretest and a current post-test (that is, a "then" and "now") design to measure student learning outcomes (Douglass et al., 2012). This evaluation method was useful to identify changes that students experienced subjectively in the student-centered framework, and the scores given by teachers together with SERU survey results may create a more subjective grade for students.

To better assess these pedagogical strategies, the following tools were recommended. Online anonymous questionnaires about the effectiveness of different teaching methods could be distributed to students. For example, students may be asked to report their confidence in different teaching methods based on the Likert scale (Stoehr et al., 2021). The commonly used scale was five points, for instance, when using a certain method to discuss a parasite with peers, students could report their confidence with 1 being not confident at all, 2 being unconfident, 3 being neutral, 4 being confident and 5 being extremely confident. The data from different majors were collected, and the following years of data could be analyzed to give a comprehensive assessment. The students' grades on human parasitology were also available for comparison among different teaching methods. And a semi-structured interview in which students were allowed to express their opinions freely was used to assess online education during the COVID-19 pandemic as well (Bıyık et al., 2021; Chen et al., 2022). Our experience may offer meaningful lessons for human parasitology teaching in other countries. At present, countries worldwide remain under the threat of the pandemic (Centers for Disease Control Prevention, 2021a), and many international students are unable to attend offline classes (The Organisation for Economic Co-operation and Development, 2021). Therefore, such a teaching model is quite suitable, and the model framework permits various adaptations based on teaching goals or countries' situations to guarantee the continuity of human parasitology teaching.

CONCLUSION

From 2019 to 2021, COVID-19 changed human parasitology education greatly in terms of both teaching methods and content. We adopted full online teaching to comply with urgent pandemic control measures and transitioned to a blended model in the present normalization stage. Different methodologies such as virtual laboratory, BOPPS model, and student-centered framework were mixed to enhance students' learning outcomes and their interest in human parasitology. The transition to online and online-offline blended teaching has boosted innovative online teaching activities and enhanced teachers' digital literacy.

During the online education, a well-structured teaching model that integrated the course preview, live lecture, review, and assessment was developed. The CBEL and FC modes were also conducted during the blended teaching of human parasitology. Moreover, we discussed the strengths along with flaws about the above teaching methods for a more subjective assessment, and some possible assessment measures were also presented. These reflections on the changes in the human parasitology teaching model can provide experience and insights for the future. According to the latest report, the Omicron variant, which may spread more easily than the original SARS-CoV-2 virus, has been detected in the United States (Centers for Disease Control Prevention, 2021b). The subsequent stage may witness further challenges because the pandemic is a dynamic situation, but our experience could prepare human parasitology teaching for a sudden switch between the present hybrid teaching method and fully online teaching under conditions of urgent pandemic control. Moreover, many interesting and innovative practices, such as teaching contests regarding human parasitology education, can be carried out to improve the development of medical education and provide fundamentals for future global crises, such as the COVID-19 pandemic.

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AUTHOR CONTRIBUTIONS

S-QD: conceptualization. S-QD and M-ZH: methodology. M-ZH, ML, Y-ND, and S-QD: writing – original draft preparation. M-ZH, WW, CZ, J-JS, J-LS, and S-QD: writing, review, and editing. S-QD, Y-ND, and ML: funding acquisition. All authors have read and agreed to the published version of the manuscript.

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