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Original Article

Comparison of learning effectiveness between physical classroom and online learning for dental education during the COVID-19 pandemic



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Abstract *Background/purpose:* Online learning has been used to continue dental education activities during the coronavirus disease 2019 (COVID-19). This study aimed to compare the learning effectiveness between physical classroom and online class learning for dental education during the COVID-19 pandemic by the questionnaire survey.

Materials and methods: A questionnaire-based online survey was used to evaluate the learning effectiveness on the dental students who took the compulsory course entitled “oral pathology and diagnosis” in School of Dentistry, National Taiwan University in 2021. Student’s *t*-test and Mann–Whitney U test were used to analyze the difference in learning effectiveness between

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physical classroom and online class learning for dental education during the COVID-19 pandemic.

Results: In this study, dental students tended to have a viewpoint that the learning effectiveness of online class learning was better than that of physical classroom learning. On the contrary, they tended to have a viewpoint that the convenience and fairness of physical classroom examination was better than that of online examination (all *P*-values < 0.001).

Conclusion: We conclude that our dental students are ready to take online courses. In terms of blended learning courses, the combination of physical classroom and online courses is the future trend of dental education. At this moment, dental schools must prepare their abilities for the implementation of online courses to respond to the COVID-19 pandemic and the next crisis, as well as for the needs of future dental education.

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Introduction

The coronavirus disease 2019 (COVID-19) pandemic caused by a severe acute respiratory disease coronavirus 2 (SARS-CoV-2) is a highly contagious disease that not only has a major impact on health, but also violates global economic and social activities. The way of transmission of this virus is through both direct contact and air droplets.^{1–3} This leads to the embarrassing situation of the government adopting a blockade or isolation policy in the end to limit the spread of infection. This policy becomes the best strategy of choice to prevent the COVID-19 pandemic from spreading widely.^{4,5} Through blockade or isolation, social distance can be maintained and direct human contact or aerosol pollution can be prevented, therefore curbing the pandemic. However, this strategy also has some adverse effects of restricting social activities.^{6,7}

Compared with the world under the COVID-19 pandemic in 2020, Taiwan still maintains a normal social life in 2020. For example, the government, schools, and hospitals all operate as usual in 2020. Unfortunately, Taiwan began to have a large number of local infections of COVID-19 at the end of April 2021. Therefore, the Taiwan's government raises the pandemic alert to the third level in May. The Ministry of Education announced that students of all levels stop attending classes in schools from May 19, 2021. Moreover, this situation continued until the end of the semester. In order not to interrupt students' learning, all schools switched to online learning for all courses.

Dental education is mainly composed of three components: lectures and problem-based learning interactions, simulated training courses, and clinical skill training. These three components all require close contact with people, and social distance cannot always be maintained during the process of the dental education.⁴ Ensuring the health of dental students is not only by strengthening the infection control protocol in the clinical practice, but also by recommending distance learning through online learning or e-learning to avoid crowding of people and spreading of the COVID-19 pandemic.⁷ Although online learning has been used as a supplementary teaching method for distance dental education since 1990, dental education based on its characteristics still has to take face-to-face education in

physical classrooms as the mainstream.⁸ Since the global outbreak of the novel coronavirus, the social lifestyles have undergone great changes. Many dental schools have been locked down because of the COVID-19 pandemic, and most of the lectures were switched to the online mode to keep on the learning progress for their dental students.⁹

The efficiency of the online learning may be affected by many factors, and there were few studies on the comparison of the difference in learning effectiveness between physical classroom and online learning for dental education in the past. However, due to timing coincidence in Taiwan in 2021, dental students who took the "oral pathology and diagnosis" course which was composed of lectures, microscopic interpretation, dental chart writing, and small group discussion in our dental school had the opportunity to experience both physical classroom and online learning in the same semester. Therefore, we also had the opportunity to study the difference in learning effectiveness between physical classroom and online learning for dental education by the participatory observation and questionnaire survey. This study aimed to evaluate the difference in responses of dental students who experienced both physical classroom and online learning during the COVID-19 pandemic. We believe that the result of this study is very important to ensure and improve the quality of dental education in the new-style social life during the COVID-19 pandemic period.

Materials and methods

Participants

Thirty-seven students who took the compulsory course entitled "oral pathology and diagnosis" in School of Dentistry, National Taiwan University were included in this study.

Teaching process and participatory observation

We adopted a diverse teaching model. There were four components in this oral pathology and diagnosis course, including lectures, microscopic interpretation, dental chart

writing, and small group discussion. The interdisciplinary problem-based learning in a small group was the teaching model. The teachers gave lectures about oral pathology and diagnosis, microscopic interpretation training about oral and dental diseases by virtual microscopy, simulated training for dental chart writing in the first three quarters of the semester. Then, based on the knowledge and skills acquired, the students had a small group discussion on the topics about oral and dental diseases in the last quarter of the semester.

Due to timing coincidence, we completed lectures, microscopic interpretation training, and dental chart writing with physical classroom learning, and then completed small group discussion with online learning. In addition, the mid-term examination (including laboratory class of microscopic examination) was held in the physical classroom, and the final examination was held online. Therefore, we experienced both modes of physical classroom and online teaching, learning, and examination in the same semester. We participated in it, observed students' reactions to different learning and examination modes, and then further designed the questionnaire survey.

Survey tool

After the final examination in June 2021, we invited all dental students who took the course of oral pathology and diagnosis to fill out the questionnaires. All dental students were invited to join in this questionnaire survey at their free will to fill out the questionnaires without the pressure from the investigators.

A semi-structured questionnaire-based online survey (Google form) was used as the survey tool to evaluate the learning effectiveness of physical classroom and online learning and examination by undergraduate dental students who took the course of oral pathology and diagnosis. The questionnaire was designed to obligate the participants to answer all the questions and to make sure that the returned electronic survey forms were all complete. The questions included the gender and investigated questions. These investigated questions included (1) the weekly learning time after class during the period of physical classroom or online class learning, (2) the learning effectiveness and the courage to speak during the physical classroom or online class learning, and (3) the agreement on the various investigated items about the comparison of learning effectiveness between the physical classroom and online class learning as well as examination. In the investigated questions of part (3), the answer was designed to let the participant to raise a score ranging from 1 to 4. If the intensity or response for each question was extremely important, the score was 4. In contrast, if the intensity or response for each question was extremely unimportant, the score was 1. The mean score was 2.5 or more, which meant that on average, answerers agreed that the investigated items were important, and the higher the score, the higher the degree of their agreement. The participants were suggested to fill the score in fresh memory. There were open questions in the final questions of parts (2) and (3) of the questionnaire. The participants could fill any suggestion and/or opinion (including advantage or disadvantage).

In addition, we divided students' examination scores into three categories, which included (1) physical classroom learning and physical classroom examination, (2) physical classroom learning and online examination, and (3) online learning and online examination. By this way, it was used to compare the differences in students' learning achievements under different learning methods and different examination methods.

Statistical analysis

All data collected were stored in excel files and used for statistical analysis. The differences in the mean scores (the degree of agreement) of various investigated items were compared between physical classroom and online learning by Student's *t*-test and Mann–Whitney U test. The result was significant if the *P*-value was less than 0.05.

Results

Demographic data

Thirty-seven students who took the course of oral pathology and diagnosis, including one third grade-year student, 34 fourth grade-year students and 2 fifth grade-year students. Among them, 34 students who filled out the questionnaires were included in this study. Of these 34 students, 22 were males and 12 were females (Table 1). The questionnaire response rate was 91.9% (34/37).

Observation process

Traditionally, our course of oral pathology and diagnosis has been carried out in the physical classroom with face-to-face education. In the past, a real microscope should be used for microscopic interpretation teaching in a microscopy laboratory. Our current microscopic laboratory class used virtual slides of histological sections. The students

Table 1 The weekly learning time after class during the period of physical classroom or online class learning.

Physical classroom learning	Male	Female	Total
Less than 1 h	0	0	0
1 h	0	0	0
2 h	2	0	2
2–4 h	2	0	2
More than 4 h	18	12	30
Total	22	12	34
Online class learning	Male	Female	Total
Less than 1 h	0	0	0
1 h	0	0	0
2 h	0	0	0
2–4 h	3	0	3
More than 4 h	19	12	31
Total	22	12	34

could use their own facility, either laptop or iPad, in a general physical classroom.¹⁰ In 2021, before the third level of the pandemic alert, we completed the lectures A for 26 h, microscopic interpretation A for 8 h, and the mid-term examination in the physical classroom. Then, we completed the lectures B for 32 h and microscopic interpretation B for 4 h after the mid-term examination in the physical classroom. Moreover, the dental chart writing was also covered in the courses mentioned above. After the third level of alert, we completed the small group discussion for 16 h and the final examination online. Therefore, we completed 70 h (81%) of courses in the physical classroom and 16 h (19%) of courses online in this semester.

We observed that our dental students all were financially able to afford the relevant computer equipment and had sufficient computer operation capabilities, so they could learn online at home or in the dormitory. There were only some technical problems, such as internet speed or software conflicts, but these could be overcome. The course of small group discussion was conducted live. Many students responded that small group discussion should be conducted in the physical classroom to have better interaction between teachers and students. They also recommended that the courses of lectures and microscopic interpretation were more suitable for online learning, because pre-recorded lectures could be watched repeatedly online, which was helpful for learning. We used an internet block system in terms of a lockdown browser such as Zuvio for an online examination. Although students could accept this test method, there were still differences in the level of computer equipment and operational capabilities among students. At the final examination, one-third of the students failed to upload their answers to the computer system, so we gave these students extra time to complete the examination, which raised questions about the fairness of the examination and the risk of cheating.

We also observed that other operational courses and clerkship courses in our dental school could only be temporarily stopped under this wave of the COVID-19 pandemic. Due to the use of the virtual microscopy, our operational courses in oral pathology and diagnosis, such as microscopic interpretation, became one of the few dental courses that could be completed in this wave of the COVID-19 pandemic.

Learning attitude of students during the physical classroom or online class learning

According to students' answers on the questionnaires, regardless of the physical classroom or online class

learning, most of their weekly learning time after class was more than 4 h (Table 1). In other words, their learning time after class would not be different due to the different ways of class. Except for the students who thought that the learning effectiveness and the courage to speak during the physical classroom or online class learning were the same, most students thought that the online class learning had better learning effectiveness (15, 44.12%), while the physical classroom learning had more courage to speak (13, 38.24%) (Table 2).

The comparisons of learning effectiveness between the physical classroom learning and online class learning as well as between the physical classroom examination and online examination

There were six investigated items for learning methods and two investigated items for examination methods (Table 3). For learning methods, these items included (1) Enable students to use time to study efficiently; (2) The operation method is friendly; (3) The image on the screen is clear; (4) The learning method is convenient; (5) Facilitate students to learn oral pathology and diagnosis; and (6) Stimulate students' interest in learning. For examination methods, these items included (7) The test method is friendly in operation; and (8) The test method is fair. The agreement for the degree of importance of each item was relatively high, and all the mean scores and the proportion of those who answered as important of each item were 2.6–3.3 and 58%–98%, respectively, except the investigated item (7) for the online examination, in which the mean score and the proportion were 2.24 and 44.12%, respectively (Table 3).

The differences in the mean scores of investigated items for learning methods and examination methods between the physical classroom and online class. The mean scores of the items (1) to (6) of online class were higher than those of physical classroom. Among them, the mean scores of the items (1), (3) and (4) were significantly higher than those of physical classroom (all *P*-values < 0.05), indicating that students tend to have a viewpoint that the learning effectiveness of online class learning is better than that of physical classroom learning. On the contrary, the mean scores of the items (7) and (8) of physical classroom were significantly higher than those of online class (all *P*-values < 0.001), indicating that students tend to have a viewpoint that the convenience and fairness of physical classroom examination is better than those of online examination.

Table 2 The learning effectiveness and the courage to speak during the physical classroom or online class learning.

		Better learning effectiveness			
		Physical classroom	Online class	Same	Total
More courage to speak	Physical classroom	4	3	6	13
	Online class	0	3	3	6
	Same	2	9	4	15
	Total	6	15	13	34

Table 3 Comparisons of learning effectiveness between the physical classroom learning and online class learning as well as between the physical classroom examination and online examination.

	Physical classroom		Online class		Student's t-test
	Mean score \pm SD	Number (%) of students who answered as important	Mean score \pm SD	Number (%) of students who answered as important	
Learning					
Enable students to use time to study efficiently	2.91 \pm 0.51	28 (82.35%)	3.21 \pm 0.54	32 (94.12%)	−2.30*
The operation method is friendly	2.97 \pm 0.58	28 (82.35%)	3.06 \pm 0.60	29 (85.29%)	−0.62
The image on the screen is clear	2.65 \pm 0.69	20 (58.82%)	3.24 \pm 0.61	31 (91.18%)	−3.73***
The learning method is convenient	2.79 \pm 0.69	24 (70.59%)	3.12 \pm 0.64	29 (85.29%)	−2.01*
Facilitate students to learn oral pathology and diagnosis	3.00 \pm 0.35	32 (94.12%)	3.15 \pm 0.44	33 (97.06%)	−1.54
Stimulate students' interest in learning	2.94 \pm 0.49	29 (85.29%)	3.00 \pm 0.49	30 (88.24%)	−0.49
Examination					
The test method is friendly in operation	3.00 \pm 0.55	29 (85.29%)	2.24 \pm 0.78	15 (44.12%)	4.67***
The test method is fair	3.21 \pm 0.48	33 (97.06%)	2.62 \pm 0.60	21 (61.76%)	4.45***

* $P < 0.05$; *** $P < 0.001$.

Open question

The free comments from the dental students for the open questions could be summarized as follows. (1) The physical classroom learning had more opportunity to interact with teachers and classmates, and could practice consultation and charting. (2) The online learning was not restricted by geography and saved commuting time. The disadvantage was that the quality of internet connection was not always stable. (3) I felt comfortable to speak and raise questions in a physical class because I was used to having face-to-face communication with the teacher. I was used to asking the teacher questions after class, and the feedback was relatively immediate. (4) I felt comfortable to speak and raise questions in an online class because I could leave a message, and there was no pressure and no need to interrupt the teacher in class. (5) It was recommended that the teaching methods for computed tomography interpretation, actual case

discussion, and participation in clinical consultation and diagnosis could stimulate my interest in learning. (6) The physical classroom examination could test the learning effectiveness and was fair. (7) The online examination had problems of equipment and internet speed differences, which might affect fairness.

The test scores of different learning methods and different examination methods

The results of the mid-term and final examinations are shown in Table 4. The test scores represented students' learning outcomes and their acquired histopathological diagnosis ability. In order to compare whether students' performance was affected by different learning methods and different examination methods, we used the median scores of lectures A, microscopic interpretation A, and lectures B to divide students into high-score and low-score groups, respectively.

Table 4 The test scores of different learning methods and different examination methods.

	Physical classroom (mean score \pm SD)	Online class (mean score \pm SD)
Physical classroom examination (mid-term examination)	Lectures A (82.8 \pm 7.3) Microscopic interpretation A (78.8 \pm 10.1)	X
Online examination (final examination)	Lectures B (55.5 \pm 16.6) Microscopic interpretation B (72.9 \pm 16.3) Dental chart writing (86.0 \pm 8.0)	Small group discussion (70.8 \pm 6.2)

Regarding high-score and low-score groups of lectures A, the performance of high-score group for lectures A was significantly better than that of the low-score group ($P < 0.001$), and the performance of the high-score group for lectures B was also significantly better than that of the low-score group ($P < 0.05$), indicating that the students' performance in lectures is not different under different test methods.

On the other hand, regarding high-score and low-score groups of microscopic interpretation A, the performance of high-score group for microscopic interpretation A was significantly better than that of the low-score group ($P < 0.001$), but there was no significant difference in the median score of microscopic interpretation B, indicating that online examination may shorten the gap of the students' performance in microscopic interpretation between high-score and low-score groups.

In addition, regarding high-score and low-score groups of lectures B, the performance of high-score group for lectures B was significantly better than that of the low-score group ($P < 0.001$), but there was no significant difference in the median score of small group discussion, also indicating that online class may shorten the gap of the students' performance between high-score and low-score groups (Table 5).

Discussion

The COVID-19 pandemic has become a major public health threat around the world without boundaries among different countries.^{11,12} Due to its highly contagious nature, it seriously affects the global economy and human physical and mental health, forcing the world to enter another new-style society.⁹ In Taiwan, dental education that has been performed for more than six decades needs a close contact with people in the past time.¹³ Before 2020, domestic dental education has still maintained the traditional teaching methods in terms of face-to-face education in the physical classroom. Due to the characteristics of dental education, the risk of cross-infection among teachers and students may be higher.¹⁴ Many countries in the world have adjusted their dental education mode since 2020 to adapt to the requirements of pandemic prevention and to maintain social distance.⁹ However, the COVID-19 pandemic in Taiwan has begun a large-scale outbreak since April 2021. Therefore, our dental education mode has also changed to online education.

Online learning which has been advocated in dental education since 1990 has become an appropriate method to adapt to the requirements of social distance.⁸ The combination of information technology has changed the teaching and learning process. By using online learning, the learning process can be carried out regardless of time and place.^{15–17} Therefore, we can maintain the social distance under the learning process during the COVID-19 pandemic. Although the main advantage of online learning during the COVID-19 pandemic is to maintain the learning process without violating social distance, it is a high-cost learning mode that depends on equipment, facilities, and technology.¹⁸ The equipment and facilities required for the learning process include the laptops of both teachers and

students, the internet system, and the technology to operate these digital devices. All these factors may be affected by the country's socio-economic conditions, the budgets of dental schools, and the financial capacity of dental students, as well as other factors, such as the motivations of both teachers and students.^{19,20}

However, for the high-cost solution of dental education with information technology, it does not seem to be a problem for the current dental schools and dental students in Taiwan. For dental schools, the use of information technology has long been integrated into various dental teaching activities, and dental teachers have already adapted to the operation of the information system. For current dental students, the burden of information equipment costs is not a problem, at most it is the adaptation and technical problems of the operation of information system. In fact, since the implementation of national health insurance in Taiwan in 1995 has enabled dentists to have a good socio-economic status and a high living standard, the domestic departments of dentistry or dental schools have become a popular choice of university departments for high-school graduates.²¹ Since then, in addition to the increase in the number of domestic dental students in Taiwan, there have also been qualitative changes of our dental students. Most dental students come from metropolitan areas and families with high socio-economic status, while students from remote areas or disadvantaged families have hardly the opportunity to enter a dental school.¹³

Since there are many operational courses in dental education, which are suitable for face-to-face education activities, we have no intention to design the online courses in the past. However, the sudden outbreak of the COVID-19 pandemic in Taiwan in April 2021 forced us to immediately change the physical classroom course to online course without enough time to prepare. We successfully completed the remaining courses online and held the final examination online to prove that our teachers and students had sufficient computer skills to complete the online class and examination. Moreover, our school and students could also afford the cost of these computer equipment. Therefore, this accidental coincidence gave us the opportunity to observe that the same students experienced both physical classroom learning and online class learning, as well as both physical classroom examination and online examination in the same course. It is worth taking this opportunity to study the role of online learning in dental education to form a new mode of dental education in the new-style social life.

From our observation and students' responses to the questionnaires, students generally believed that online class learning had a better learning effectiveness, especially in terms of effective usage of time, clear course screens, and convenient learning method. Some students suggested that the lectures and microscopic interpretation courses should only use the online class, and the pre-recorded courses were convenient for students to watch and study repeatedly. In addition, some students dared to express their opinions and ask questions online. However, many students also thought that face-to-face interaction was very important in the physical classroom learning, and the practical courses still needed to be conducted in the

Table 5 Grouping by median score for comparisons of the test scores of different learning methods and different examination methods.

	Grouping by median score of lectures A (83): high lectures A score (≥ 83) group and low lectures A score (< 83) group			
	Median score of lectures A	Mann–Whitney U test	Median score of lectures B	Mann–Whitney U test
High lectures A score group (n = 19)	87.5	<0.001***	61	106.50*
Low lectures A score group (n = 18)	78.3		52	
	Grouping by median score of microscopic interpretation A score (83): high micro A score (≥ 83) group and low micro A score (< 83) group			
	Median score of micro A	Mann–Whitney U test	Median score of micro B	Mann–Whitney U test
High micro A score group (n = 19)	85	<0.001***	82	111.50
Low micro A score group (n = 18)	71		75.5	
	Grouping by median score of lectures B (58): high lectures B score (≥ 58) group and low lectures B score (< 58) group			
	Median score of lectures B	Mann–Whitney U test	Median score of small group discussion	Mann–Whitney U test
High lectures B score group (n = 20)	63.5	<0.001***	67	168.5
Low lectures B score group (n = 17)	44		67	

* $P < 0.05$; *** $P < 0.001$.

physical classroom. In addition, most students thought that online examination had operational and fairness issues and prefer physical classroom examination.

From the perspective of teachers, we believe that physical classroom teaching can directly catch the students' responses to know whether they are listening to the lecture or thinking about other things. Online teaching often needs to force students to answer. For students who do not concentrate on the online class, it seems difficult to control the online class. Therefore, we believe that the learning quality of online learning for students who are not willing to learn independently may be worse than that of physical classroom learning. We also used some skills in online class teaching, such as asking students to use mobile phone messages to answer questions, so that we could observe individual students' reactions in the online class. In addition, in online examination, there were some computer operation problems such as inflexible computer time settings, crashes, and slow internet speed, but physical classroom examination could be adjusted according to students' responses. In addition, online examination needed to rely on the answering speed or case questions to avoid cheating and fairness issues.

Due to the limitations of this study, we could not attribute the difference in test scores of students to learning or examination methods. Because the test questions were essentially different, the difference in test scores was still related to the difference in the test questions. Therefore, we used the median score to classify the groups, and found that the micro A score of the high micro A score group was significantly higher, but their micro B score was not significantly higher, indicating that in online examination, the difference in performance between the high-score group and the low-score group is shortened. In addition, the lectures B score of the high lectures B score group was significantly higher, but their small group discussion score was not significantly higher, indicating that in online learning, the difference in performance between the high-score group and the low-score group is shortened. This result is very interesting, indicating that blended physical classroom and online learning seems to affect students' learning effectiveness, but this needs more studies to confirm.

Blended physical classroom and online learning is a dual-track learning that uses face-to-face activities and internet technology. It combines the advantages of two learning environments. Through interaction with teachers and students, it extends learning opportunities and enhances learning effectiveness. There is no consistent standard or definition for blended physical classroom and online courses. Generally, it means that more than 30% but not more than 80% of the course content is conducted online. For students who adopt blended learning, the learning effectiveness is improved by 5%–10% compared to that of face-to-face activities.²² An unexpected coincidence forced us to change 19% of the original course to online teaching. Although this ratio might not meet the standard or definition of blended physical classroom and online course, our students became the first batch of dental students to participate in blended learning. We also found that blended learning might improve students' learning effectiveness in dental education.

We conclude that our students are ready to take online courses. In terms of blended learning courses, the combination of physical courses and online courses will be the future trend of dental education. However, the practical courses in dental education must still be based on physical courses, especially the internship course which helps students understand the real-world situation in practice. Therefore, at this moment, dental schools must prepare their abilities for the implementation of online courses to respond to the COVID-19 pandemic and the next crisis, as well as for the needs of future dental education. Finally, it is the most important to ensure the quality of education to meet the standard of dental education.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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