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Challenges and coping strategies of online learning for college students in the context of COVID-19: A survey of Chinese universities

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ABSTRACT

The COVID-19 epidemic has disrupted the normal teaching and learning in universities, which poses significant challenges to higher education. The traditional face-to-face learning mode has been switched to online (distance) learning, causing various influences on students' academic performance, physical and psychological well-being. As higher education plays a central role in technology innovation and society development, it is of great importance to investigate and improve online learning in the context of COVID-19. This study distributed online questionnaires to undergraduate and postgraduate students from 30 provinces or municipalities in China (covering 88% of the whole country). Results indicate that online learning mode is more likely to reduce the academic performance of lower-grade students (e.g., freshman and sophomore). The learning environment could be one of essential factors affecting the academic performance during online education. Studying at home or dormitory is more evidently correlated with academic performance decline. Regarding the physical and mental health during online learning, most students had experienced eye strain (84%) and cervical stiff (79%), while anxiety is the most prominent mental issue (66% of occurrence). Several coping strategies are suggested to improve the online learning in post-pandemic era, which is essential for higher education and promoting a civilized and sustainable society.

1. Introduction

COVID-19 poses great challenges and opportunities for economic, social and educational development (Mouratidis & Papagiannakis, 2021; Wang, 2021). Globally, till April 25th of 2022, 507,501,771 confirmed cases of COVID-19 have been reported to WHO, including 6, 220,390 deaths (WHO, 2022). Since January 2022, recurring COVID-19 outbreaks have occurred in multiple places/regions, with the number of new confirmed cases in January reaching a two-year high. As a result of COVID-19, countries have adopted diverse control strategies to reduce the spread of the epidemic, such as keeping social distance and lockdown (Balest & Stawinoga, 2022; Ren et al., 2021), but various sectors have also been affected to varying degrees. Among them, the education sector has been significantly affected, including significant changes in the way of knowledge transmission and the environment of teaching and learning. Many universities have switched to online education accordingly to react to the COVID-19 epidemic (Mouratidis & Papagiannakis, 2021). Compared to face-to-face learning, online (distance) learning has different characteristics such as physical distance (Patricia

Aguilera-Hermida, 2020), technology dependency (Patricia Aguilera-Hermida, 2020), network requirements (Truzoli et al., 2021), low practicability (Jiang, Wu et al., 2021), high hardware requirements (Jiang, et al., 2021), and lack of teaching experience (Jiang, Wu et al., 2021), which has an immediate and long-term impact on students' physiology, psychology and life (Dodd et al., 2021; Jiang, Wu et al., 2021). Besides, an important difference of online learning that distinguishes from face-to-face learning is the difficulty of prompting learning communities that helps to enhance teacher-student empathy and social interactions between students (Brouwer et al., 2022). Learning communities in turn can benefit students' academic performance, physical and mental health. These difference or factors could bring profound changes and challenge to higher education which is critical for technology innovation and shaping civilized society for sustainable development (Aleixo et al., 2021; Dóci et al., 2022).

College students have a unique set of life and psychological characteristics as they have just completed high school and entered a relatively independent environment. In the period of regular epidemic prevention and control, college students, as the group of students that may be

vulnerable to be neglected (Tasso et al., 2021), need more care and support for their academic performance, physical and psychological health. Pedrelli et al., and Wilens (2015) noted that traditional college students are typically young, and in addition to the stresses associated with their academic load, these students may have the responsibilities of being an adult without having fully acquired the skills and cognitive maturity. The university period is a critical time for shaping students' personalities and developing their talents (Fadeeva & Mochizuki, 2010). For a long time, universities have played an important role in shaping future sustainable development of the world. Higher education contributes to the training and development of university students' knowledge and professional skills through its main functions of teaching, research, and extension to address various scientific and social issues (Rieckmann, 2012). In addition, online education also provides more opportunities to complete degrees online, which is of great importance for higher education (Alqurashi, 2019).

In the context of regular epidemic prevention and control, the study and living environment, psychological condition, social environment and life support of college students have changed dramatically (Jiang, Gu, Liu, Song & Jiang, 2021; Lederer et al., 2021; Perz et al., 2022; Tasso et al., 2021). This in turn has an impact on college students' behavioral, psychological and academic performance, such as high frequency use of social media (e.g., Sina Weibo or Twitter), inattention and anxiety. These factors can adversely affect academic performance (Fu et al., 2021), which poses a great challenge to talent cultivation in higher education and the sustainable development of society. For instance, Mohan (Mohan et al., 2021) et al. used a combination of questionnaire and experiments in their research and found that online learning caused a significant increase in eyestrain and affected students' physical health during the COVID-19 pandemic. Conrad (Conrad et al., 2021) et al. noted through their study that the frequency of self-reported worry, grief, loneliness, depression, and anxiety among college students significantly increased during the COVID-19 outbreak, affecting students' psychological well-being. Hasan and Bao (Hasan & Bao, 2020) investigated the perceptions of Bangladeshi university students about online learning and the results showed that although the university students expressed understanding towards online learning, a large proportion of them expressed concern about the loss of youth. Kapasia (Kapasia et al., 2020) et al. investigated the problems in online learning among college students, and the study pointed out that the learning environment and learning devices have a prominent impact on the learning performance and psychological changes of college students. In addition, a study about online learning showed that the COVID-19 increased the psychological stress of Chinese college students and the psychological state during online learning was correlated with the subjects' grade, gender and major (Wang & Zhao, 2020).

In terms of academic performance in online learning, a large number of studies have shown that factors such as student gender (Hashemi, 2021; Prowse et al., 2021), student grade (Jung & An, 2021), learning environment (Kapasia et al., 2020), student physical health (Latino et al., 2021), student mental health (Tasso et al., 2021), learning duration (Gonzalez et al., 2020), learning strategies (Gonzalez et al., 2020), and social media usage (Prowse et al., 2021) all have certain impacts on the online learning. For instances, Wang and Zhao investigated the impact of COVID-19 on anxiety in Chinese university students (Wang & Zhao, 2020). The study found that Chinese undergraduate students shows high-level of anxiety during COVID-19, but the study only surveyed undergraduate students of one university which may not be representative for the whole China. Dodd et al. (2021) studied the Australian university students about their psychological wellbeing and academic performance during COVID-19, but the surveyed students are limited in one university. Aguilera-Hermida (2020) investigated the activities, attitude views, feelings, and educational experiences of students during online learning, but the physical health is not included. Although several studies have been conducted to explore the influence of psychological, physiological and contextual factors on online learning during COVID-19, there are still limitations in terms of the diversity in subjects and research perspectives.

Therefore, it is necessary to conduct research on academic performance of college students in online learning during the context of epidemic prevention and control, especially increasing the diversity of surveyed subjects to reflect a more general situation. This paper focuses on the influencing factors and correlations to the performance of college students' online learning in China. Electronic questionnaires (considering the diversity of subjects' location, major, grade, gender, and influencing factors) and quantitative assessment tools are used to analyze performance and encountered challenges of Chinses college students in online learning. Physical and mental health are also discussed with some recommendations. Then, improvement strategies are suggested, which provides decision support for effectively enhancing online learning performance, physical and mental health of college students. It can also provide guidance and suggestions for online education and sustainable social development in China and the world.

2. Methodology

This paper aims to investigate the factors influencing online learning of university students during the regular epidemic prevention and control. The questionnaires were distributed online through "Questionnaire Star" to university students. In order to make the results more general, the questionnaire was distributed to subjects with/in different cities, genders, grades, and majors. According to statistics, the regions covered by the questionnaire include: Beijing, Shanghai, Jiangsu, Guangdong, Hainan, Xinjiang and other 30 provinces or municipalities. The majors covered by the questionnaire include: science, engineering, medicine, literature, art, history, philosophy, economics, management, law, education, etc. A total of 645 questionnaires were received, of which 622 were valid and 23 were invalid (invalid rate 3.6%). The invalid questionnaires were eliminated based on response time, and the abnormal questionnaires with response time lower than 60s (too fast) or longer than 600s (unreasonably long) were eliminated based on pre-test of the questionnaire completion.

Questions were structured in five-level categorial options that can be easily transferred to a Likert scale for a quantitative and straightforward analysis. The Likert scale quantifies the options of the questionnaire into equidistant scales ranging from "Strongly Agree" to "Strongly Disagree" so the survey maker can get a holistic view of subjects' opinions. This study numbers Likert items as 5 (Strongly Agree), 4, 3 (Neutral), 2, 1 (Strongly Disagree) depending on the degree of agreement. The total score obtained by weighting the percentage of subjects in a particular group on each option by Likert scale corresponding to that option gives a more intuitional indication of the subjects' status (Eq. (1)).

$$LP = \sum_{i=1}^{5} S_i \times P_i \tag{1}$$

In Eq. (1), "LP" is the Likert point for a certain item, S_i is Likert scale (1, 2, …, 5) and P_i is the percentage of the corresponding category i.

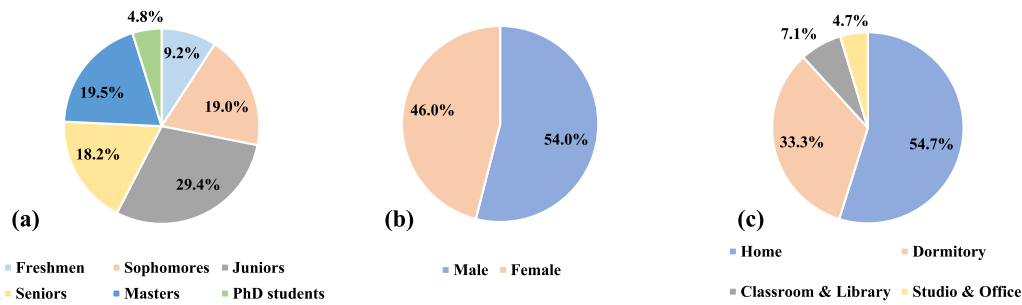$$\rho_{X,\ Y} = cov(X, Y) / \sigma_X \sigma_Y \tag{2}$$

Fig. 1. (a) Subjects' grade distribution;(b) Subjects' gender distribution;(c) Distribution of subjects' online learning environment (not include "Others").

Table 1
Gender and online learning environment by grade.

Grade	Gender		Online Learning Environment			
	Male	Female	Home	Dormitory	Classroom & Library	Studio & Office
Freshmen	38.6%	61.4%	77.2%	19.3%	3.5%	0.0%
Sophomores	50.0%	50.0%	54.2%	37.3%	7.6%	0.0%
Juniors	56.3%	43.7%	69.9%	20.8%	8.7%	0.6%
Seniors	59.3%	40.7%	47.8%	39.8%	12.4%	0.0%
Masters	56.2%	43.8%	35.5%	47.9%	0.8%	14.9%
PhD students	56.7%	43.3%	23.3%	36.7%	6.7%	33.3%

In Eq. (2), "*cov*" is the covariance, σ_X and σ_Y are the standard deviation of variable X and Y.

The collected questionnaire data is pre-processed and analyzed using the SPSS-AU (Statistical Product and Service Software Automatically) platform which supports the processing of online data. The data analysis processes are as follows:

- For the relationship between the definite category data obtained from the single choice questions, Cross Tabulations and chi-square test are used.
- For the linear relationship between different groups of definite distance data, the commonly used Pearson correlation coefficient is used (Eq. (2)), the closer the coefficient r to "±1", the stronger the correlation, and the closer to "0", the weaker the correlation.

Fig. 1(a) reports the grade distribution of the 622 subjects after excluding invalid questionnaires: Freshmen (9.2%), sophomores (19.0%), juniors (29.4%), seniors (18.2%), masters (19.425%), and PhD students (4.8%). The results in Fig. 1(b) show that 46.0% of the valid questionnaires were male and 54.0% were female. The ratio of males to females is almost homogeneous in all grades. The questionnaire divides online learning environment into four broad categories, and subjects who do not fit the profile could choose others. Fig. 1(c) shows that during the epidemic, college students basically studied at home (54.7%) or at school (33.3%), and only a small percentage chose to study in school classrooms and libraries (7.1%) or graduate studios and offices (4.7%). Table 1 shows the gender and online environment in different

grades.

There were 17 questions in the survey (see Appendix B: Sample questionnaire), 7 subject's background survey questions, 7 subjective polling questions, 1 geographic location question, and 2 suggestion or opinion gathering questions. The subjects' background survey questions included: grade, gender, major category, whether they have online learning experience, duration of online learning, learning environment, and teacher's teaching style; the subjective polling questions included: subjective preference, evaluation of learning difficulty, self-evaluation of performance, mastery level, internet recreation time, self-evaluation of physical and psychological condition, and difficulties encountered in online learning; the suggestions or opinions section was mainly used to respond to the main problems, so as to facilitate coping strategies for online learning.

3. Results

This section analyzes the relationship between the states of online learning performance (i.e., academic performance), "physical-psychological" well-being of college students and influencing factors (grade, gender, learning environment) in the context of regular epidemic prevention and control.

3.1. Correlation analysis of online academic performance

Tables A1-A2 in Appendix A show the correlation between

Table 2
Academic performance improvement of college students in different grades.

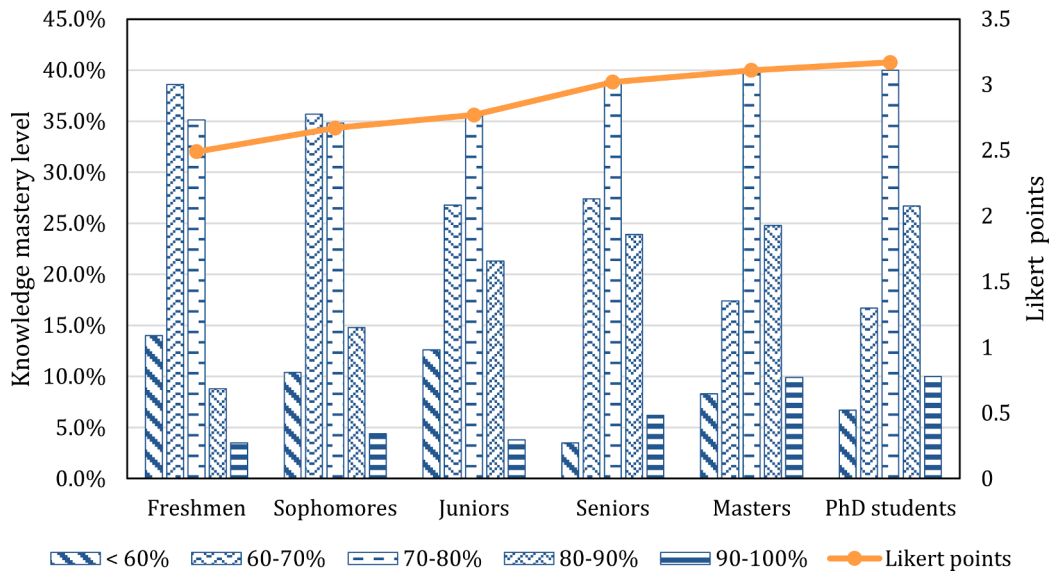| Academic performance	Dramatic drop	Drop	No effect	Upgrade	Dramatic upgrade	Total points
Grade\Score	1	2	3	4	5	
Freshmen	10.5%	64.9%	17.5%	3.5%	3.5%	2.2456
Sophomores	4.4%	53.0%	39.1%	2.6%	0.9%	2.4261
Juniors	10.9%	45.9%	39.3%	2.7%	1.1%	2.3712
Seniors	6.2%	34.5%	46.0%	10.6%	2.7%	2.6900
Masters	3.3%	34.7%	55.4%	5.0%	1.7%	2.6693
PhD students	10.0%	33.3%	46.7%	3.3%	6.7%	2.6334

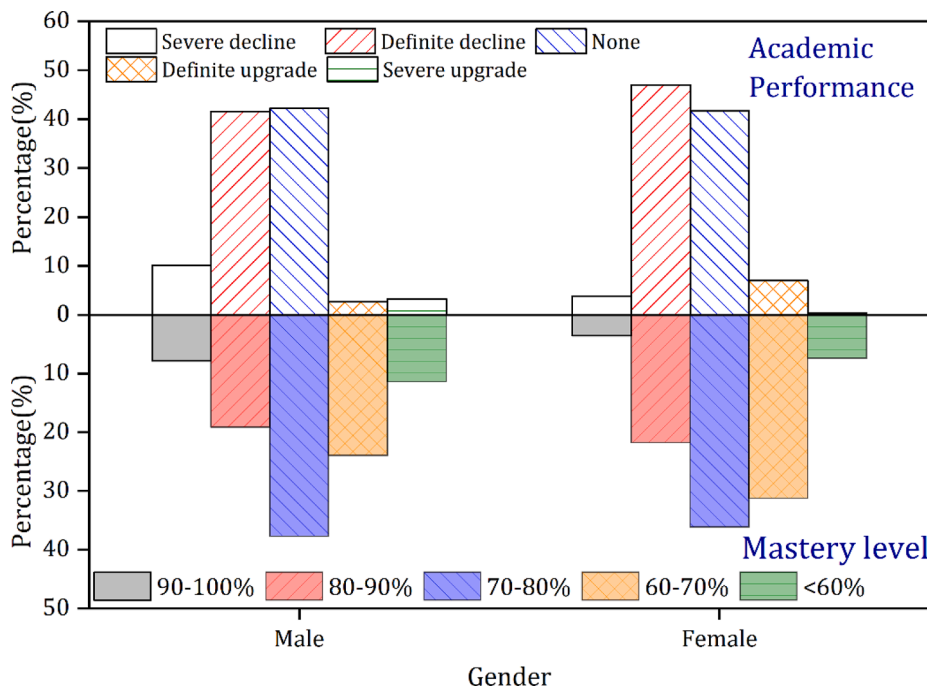**Fig. 2.** Knowledge mastery for college students in different grades.

Fig. 3. Comparison of academic performance under different genders.

influencing (subjective and objective) factors and performance of online learning in this survey. The subjective factors include time of online entertainment per day, preference level for online learning, and "physical-psychological" well-being (corresponding to questionnaire questions 8, 12, 13, and 14). The objective factors include grade, gender, and learning environment, corresponding to questions 1-7. The learning performance corresponds to questions 9-11. Appendix B Regarding the subjective factors, "physical-psychological" well-being and preference level for online learning show relatively obvious correlations, for which online learning performance with the Pearson correlation coefficient ranging from -0.455 to -0.164 and nine of nine parameters showing significant "99% confidence" (see Table A1, **p < 0.01). Correlation

was also observed between preference level for online learning and "physical-psychological" well-being with the Pearson correlation coefficient ranging from 0.197 to 0.336 and five of eight parameters showing significant "95% confidence" (see Table A3, *p < 0.05).

According to Tables A1-A3, among all the surveyed objective factors, grade and online learning environment show strong correlation with online learning performance and "physical-psychological" well-being. The correlation between gender and learning performance was relatively insignificant. However, a strong correlation was found between gender and "physical-psychological" well-being (see Table A3). Considering the potential correlation between "physical-psychological" well-being and learning performance, it is also necessary to explore the
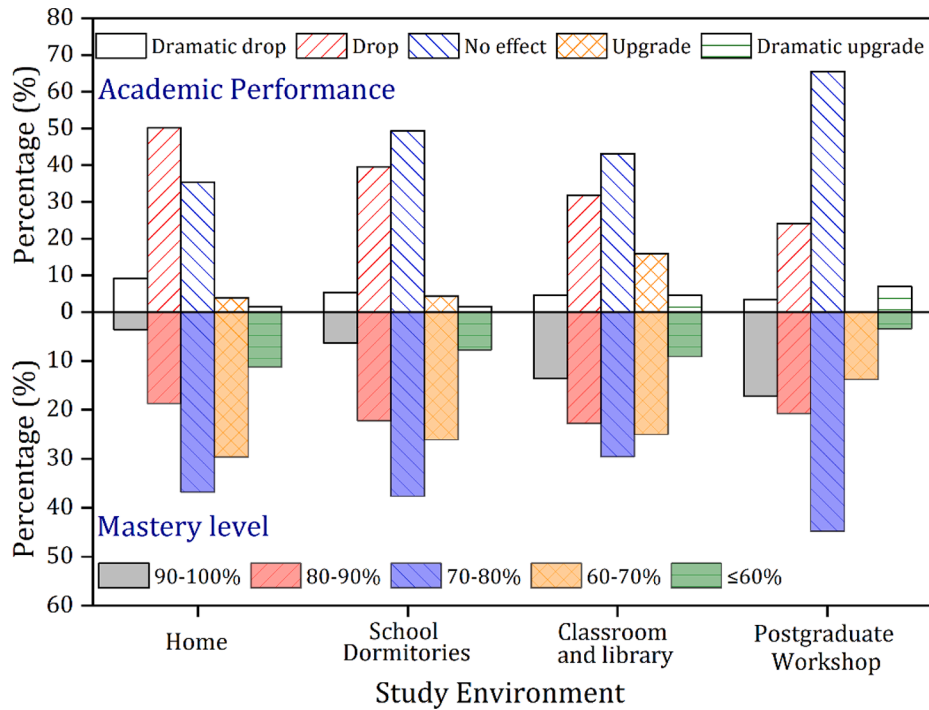
Fig. 4. Comparison of academic performance and knowledge mastery level under different learning environment.

Table 3
Occurring frequency of physical health issues for college students at different grades.

Grade	None	Once a month	Once a week	Once per three days	Every day
Freshmen	24.6%	13.2%	21.9%	15.8%	24.6%
Sophomores	33.1%	15.2%	18.9%	15.4%	17.4%
Juniors	28.8%	12.7%	17.4%	17.9%	23.2%
Seniors	33.6%	12.0%	20.1%	17.0%	17.3%
Masters	22.3%	12.2%	21.9%	18.4%	25.2%
PhD students	26.7%	16.7%	20.0%	10.0%	26.7%

influential relationship between gender, "physical-psychological" well-being and learning performance.

3.2. The impact of grade, gender and learning environment on academic performance

3.2.1. The impact of grade on academic performance

Table 2 shows the total points (calculated based on Likert scale) of academic performance improvement for college students in different grades. For students such as freshmen, sophomores and juniors, the total points of academic performance improvement were less than 2.5 (the higher point indicating the greater overall improvement of academic performance). For higher-grade students, the total points of perceived improvement in academic performance show an uptrend, with the highest total point of 2.69 for seniors.

Fig. 2 shows the percentage of different knowledge mastery levels and Likert total points of college students at each grade. It can be seen that students' mastery of knowledge gradually became better as the grade level increased. In particular, the total point of freshmen was 21.5% lower than those of PhD students. This indicates that online learning made it difficult for most lower-grade students.

In general, the current online learning mode was more prone to degrade academic performance of lower-grade students (freshman and sophomore). This may be related to the learning environment for different grades (further discussed in Section 4).

3.2.2. The impact of gender on academic performance

Fig. 3 (upper part) shows the academic performance of male and female students during online learning. The percentage of decline in academic performance is around 50% for both male and female

Table 4
Occurring frequency of psychological issues for college students at different grades.

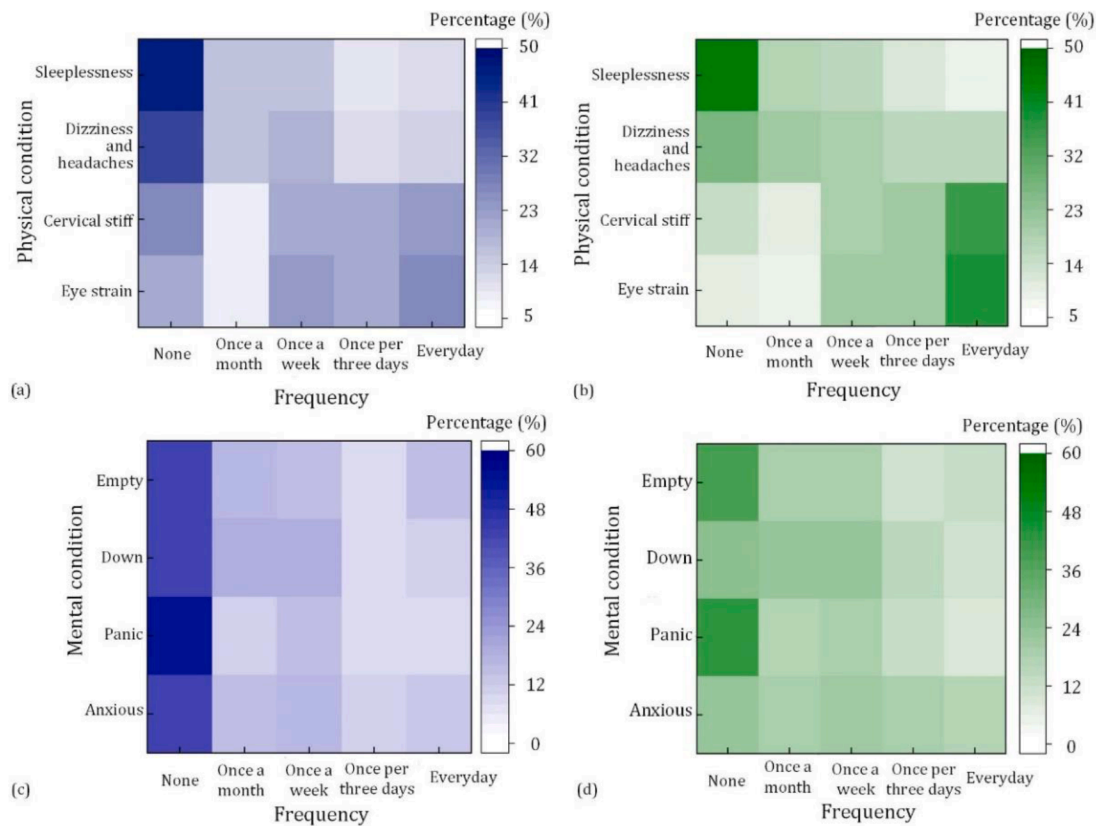| Grade	None	Once a month	Once a week	Once per three days	Every day
Freshmen	32.5%	12.7%	22.4%	12.7%	19.7%
Sophomores	43.3%	18.9%	19.1%	10.0%	8.7%
Juniors	35.4%	16.7%	20.8%	12.6%	14.6%
Seniors	51.3%	20.6%	11.5%	9.1%	7.5%
Masters	33.7%	15.1%	20.7%	15.9%	14.7%
PhD students	52.5%	23.3%	5.8%	5.0%	13.3%

Fig. 5. Physical and mental problems during online learning: (a) & (c) Male; (b) & (d) Female.

Table 5
Frequency of student's overall physical health being affected in different learning environments.

Learning environment	None	Once a month	Once a week	Once per three days	Every day
Home	27.6%	12.8%	19.5%	17.3%	22.9%
Dormitory	30.0%	13.7%	20.1%	16.7%	19.7%
Classroom and library	35.2%	11.9%	14.8%	13.6%	24.4%
Postgraduate studio	21.6%	17.2%	22.4%	18.1%	20.7%

students, and that of upgrade in academic performance is below 10%. From the knowledge mastery (Fig. 3 lower part), the percentage of male and female students who are able to have a good mastery of knowledge (i.e., 70-100%) is 65% and 62%, respectively. Hence, gender does not have significant impacts on academic performance and knowledge mastery level.

3.2.3. The impact of learning environment on academic performance

Fig. 4 (upper part) shows the effect of different learning environments on academic performance. Of these, "study in home" resulted in a decrease in academic performance for 59.35% of students. Fig. 4 (lower part) demonstrates the impacts of learning environment on knowledge

mastery. The data shows that the percentage of students with "knowledge mastery level greater than 70%" increased from 59.05% in "study in home" to 82.76% in "office or studio". These results indicate that the online learning environment could be a key factor affecting student's performance which requires detailed discussion and analysis.

3.3. The impact of grade, gender and learning environment on physical and mental conditions

3.3.1. The correlation between grade, physical and mental conditions

Table 3 indicates the occurring frequency of physical well-being issues for college students in different grades. The integrated physical

Table 6
Frequency of student's overall psychological issues being affected in different learning environments.

Learning environment	None	Once a month	Once a week	Once per three days	Every day
Home	35.3%	17.4%	20.4%	11.1%	15.8%
Dormitory	33.3%	17.9%	15.7%	12.4%	8.2%
Classroom and library	38.6%	21.0%	14.2%	13.1%	13.1%
Office and postgraduate studio	50.9%	10.4%	17.2%	13.8%	7.8%

Table 7

The relationship between the frequency of different physical and mental health issues and academic performance.

Frequency of physical and mental health issues	Academic performance			Knowledge mastery	
	Drop	None	Upgrade	60-100%	<60%
Everyday	69.6%	26.0%	4.5%	77.2%	22.8%
Once per three days	55.9%	37.6%	6.5%	89.4%	10.6%
Once a week	54.6%	39.9%	5.4%	92.6%	7.5%
Once a month	52.1%	43.3%	4.6%	94.2%	5.8%
None	38.1%	52.7%	9.2%	94.8%	5.2%

well-being includes eye strain, cervical stiff, dizziness & headache, and sleeplessness. Results show that the college students at different grades had different levels of physical well-being problems, with the percentage of daily frequency reaching more than 17%. The percentages of freshmen, masters and PhD students with physical well-being problems at least once a month were relatively higher than those of other grades, which is 75%, 78% and 73% respectively.

Generally, the physical well-being level of college students in different grades appeared to be deteriorated during online learning. The physical health issues of freshmen, masters and PhD students are relatively more prominent, which requires particular attention and care.

Table 4 displays the percentage of affected frequency of psychological well-being for college students at different grades. The combined psychological well-being involves anxiety (66% of occurrence, the most prominent), panic, depression and emptiness. Freshmen with potential psychological problems every day reach a maximum of about 20%. In terms of the frequency of at least once a month, the percentages of juniors and masters with psychological well-being problems are larger, i. e., 65% and 66% respectively.

In summary, the psychological well-being of freshmen, juniors and masters appeared to be relatively worrisome among all grades of students. There is a need for targeted mitigation of psychological well-being problems among college students, especially in the phase of COVID-19 that may have irregular epidemic prevention control and online education.

3.3.2. The correlation of gender on physical and mental conditions

The surveyed data shows that online learning tends to aggravate physical and mental problems for university students. Fig. 5 **(a)-(b)**

depicts the physical problems during online learning of males and females. A total of 79% of students had experienced eye strain, with females accounting for the majority (49%). The percentage of getting cervical stiff per day is 18% for females with a total percentage of 30%. Fig. 5 **(c)-(d)** shows the psychological problems during online learning. The percentage of males who do not occur psychological problems is more than 40%, while that of females is around 30%. It shows that females are more likely to have psychological problems during online learning. Among these four psychological problems, more than 80% of females had felt anxious and down, which is about 10% more than that of males. Thus, females are found to be more prone to physical and psychological problems than males.

3.3.3. The correction between learning environment, physical and mental conditions

From Table 5, the learning environment with the lowest percentage being affected by physical health issues is classrooms and libraries (around 35% of students has no issues). Overall, the percentage of "having physical health problem each day" is more than 19% for all the students. Table 6 shows the frequencies of students' psychological status affected by different learning environments. As the table shows, students studying at home had the highest probability of having psychological issues (15.8%). When considering the frequency of "at least once a month", students studying at home and dormitory are more likely to be mentally affected than studying in classrooms and libraries, offices and studios. Thus, online learning environment can have varying degrees of negative impacts on physical and mental health. Particularly, studying at home could lead to a higher chance for mental health problems.

3.4. The impact of physical and mental on the academic performance

Table 7 shows the effect of physical and mental health status on

Table 8

Online learning experiences of students at different grades.

Grade	More than 2 semesters	One semester	None
Freshmen	49.1%	49.1%	1.8%
Sophomores	49.2%	42.4%	8.5%
Juniors	70.5%	28.4%	1.1%
Seniors	65.5%	31.0%	3.5%
Masters	51.2%	38.0%	10.7%
PhD students	23.3%	33.3%	43.3%

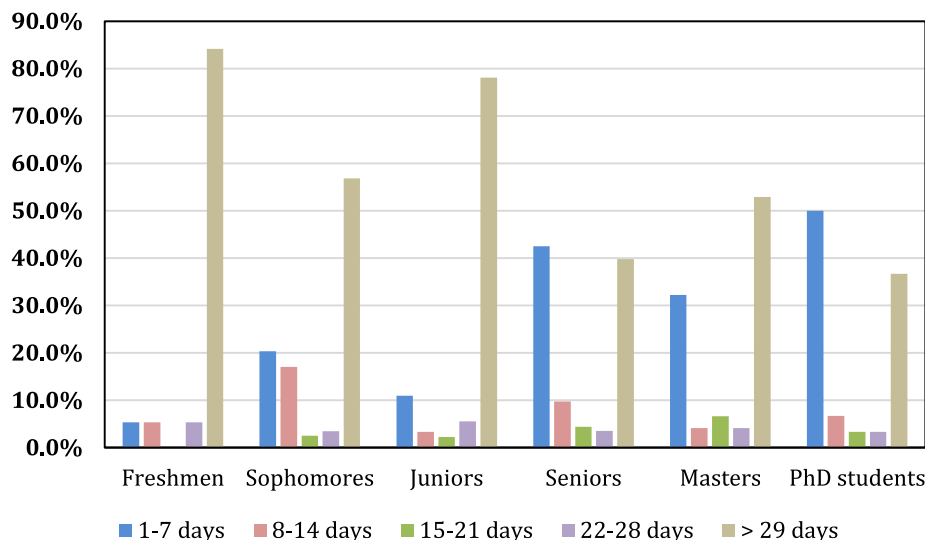**Fig. 6.** Percentage of duration of online learning for different grades.
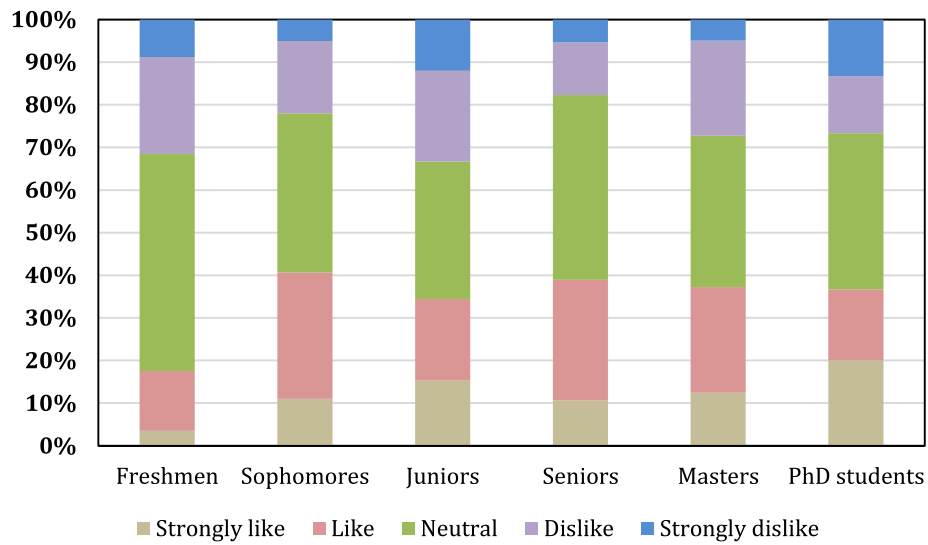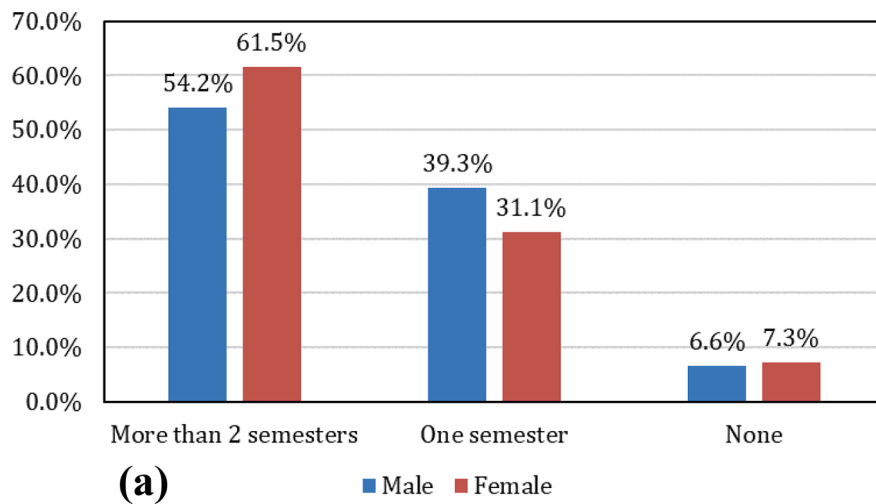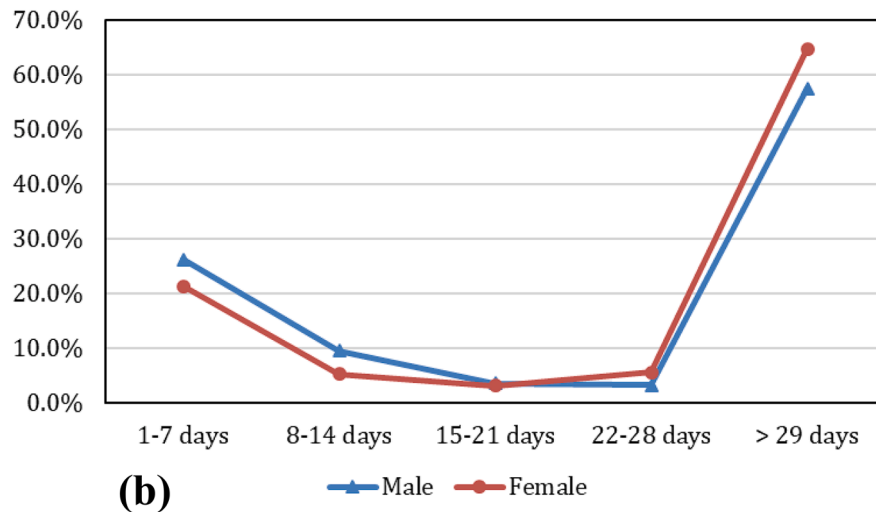
Fig. 7. Students' preference of online learning for different grades.

(a)

(b)

Fig. 8. **(a)** Online learning experiences and **(b)** learning duration for different genders.

Table 9
Percentage of duration of online learning for different learning environment.

	1-7 days	8-14 days	15-21 days	22-28 days	Above 29 days
Home	9.4%	2.7%	1.8%	3.5%	82.7%
Dormitories	39.1%	15.0%	5.3%	5.3%	35.3%
Classroom	47.7%	11.4%	2.3%	4.6%	34.1%
Workshop	44.8%	6.9%	10.3%	6.9%	31.0%

academic performance. As the frequency of physical and mental health problems increases, the rate of "decline in performance" increases. The percentage of declining grades increased from 38.10% to 69.57% when physical and mental health problems have gradually increased from none to daily. As the frequency of physical and mental health problems increases, the percentage of students whose mastery of knowledge is 60-100% gradually decreases and learning efficiency decreases. In summary, physical and mental health issues have a significant negative impact on academic performance during online learning.

4. Discussions

In this section, the challenges of academic performance, physical and mental condition of college students during online learning are further explored. Meanwhile, improvement measures for the existing online learning pattern are proposed to effectively enhance college students' academic performance and "physical-psychological" well-being. It can provide suggestions for the normalization of online education and sustainable social development.

4.1. The analysis of grade on academic performance, physical and mental status

It is found that lower-grade students mostly study at home or in the dormitory (as shown in Table 1), which may lack a positive learning environment and interaction with peers or teachers. Most of senior students studies in classrooms or studios, and has a relatively better learning environment compared to the lower grades. The potential reasons for physical problems (eye strain, cervical stiff, dizziness and headaches, sleeplessness, etc.) among college students may be the long duration of online learning, as shown in Fig. 6. For instance, the percentage of freshmen who has online learning duration above 29 days is around 84%, while the physical health problems are prominent among them.

The overall mental condition (anxious, panic, down and empty) of college juniors is relatively worrisome. It may be due to the largest percentage of juniors with "more than two semesters of online learning experience" is up to 70% (Table 8), resulting in a maximum of 33% of juniors disliking online learning (Fig. 7). Besides, PhD students are found to have the highest percentage of "Strongly dislike" (Fig. 7), which might be due to a high ratio of them is at the beginning of the online learning (i. e., 1-7days in Fig. 6) in which they would feel difficult in adaption. Psychological well-being problems are also common among freshmen and masters, which may be related to the long duration of online learning or the pressure of research (Butler-Rees & Robinson, 2020).

4.2. The analysis of gender on physical and mental

The correlation between gender and physical and psychological conditions during online learning is analyzed in this work. The results show that females are more likely than males to suffer from physical and mental health problems, such as eye strain and cervical stiffness. As shown in Fig. 8, a high proportion of females have more than 2 semesters of online learning experience and online learning duration above 29 days, which is consistent with the findings of McIntyre et al. (2014).

4.3. The analysis of learning environment on academic performance, physical and mental conditions

According to the analysis in Section 3.2.3, the learning environment may be one of the essential factors affecting the academic performance. "Studying at home or dormitory" is more likely to lead to a decline in academic performance and efficiency. It is probably due to the lack of a suitable or adequate learning environment, which is consistent with the analysis described in Section 4.1.

The online learning environment may have negative effects both on physical and mental health. For example, students must use electronic communication devices when participating in online courses, which might lead to eyestrain (McIntyre et al., 2014). Particularly, students are more likely to have mental health problems when studying at home or dormitory. This may be partially due to the relatively longer duration of online learning associated with studying at home and dormitory in this survey (see Table 9).

4.4. Suggestions for online learning

Firstly, a hierarchical arrangement of online learning programs is suggested for college students, considering the volume of study and research tasks at each stage. A flexible plan to increase exercise time and improve physical fitness can be designed. Regular exercise is particularly important during COVID-19 as it can enhance the human immune system (Wang et al., 2022). Suitable reduction of class time per session and an appropriate increase in the number of class sessions are recommended. Increasing the exercise time between classes can also be helpful, such as adding cervical spine relaxation exercises.

Secondly, it is recommended that online interaction can be added based on requirements of different grades and the learning environment. In particular, lower-grade students (freshman and sophomore) who study at home or dormitory can be involved in more class discussions. The learning environment of home or dormitory could be inadequate and not suitable for online learning (as discussed by Cuerdo-Vilches et al. (2021)). Thus, improvement strategies of space design and renovation could be investigated in the future to create an online-learning-oriented environment. For instance, since the top two difficulties encountered in the online learning are "Insufficient learning atmosphere" and "Inefficient learning" (Table A4), a virtual learning community can be created through the efforts of teachers and students. Besides, psychological survey or one-on-one counseling could be conducted in a reasonable manner based on the grades, male and female students. More efforts should be invested in improving the mental health of students who are exposed to mental health risks, especially during the phase of regular epidemic prevention and control. To alleviate the psychological problems during online learning, it is recommended to add some interactive sessions in each online course to increase the interest of the class.

Thirdly, some of the strategies used in traditional face-to-face education are suggested to be integrated into the online learning. For example, students can minimize the focus time of electronic screens and use paper-based courseware or writing for course interaction. In this case, smart wearable devices can be suggested to assist the health management of

students engaged in online learning (Nagarajan et al., 2021). Appropriate scheduling of outdoor activity courses is proposed to relax students' physical and mental well-being (when outdoor activity is available), thus in turn promoting online learning efficiency and academic performance.

4.5. Limitation and future direction

This paper investigates college students' academic performance and "physical-psychological" well-being in China under the regular epidemic prevention and control. The limitations of this work are as follows. Future studies could increase the questionnaire sample involving more countries to provide more comprehensive analysis under different online learning modes. In this study, major influencing factors were discussed such as grade, gender and learning environment. The student age is not specifically investigated and it is reflected by grades. However, the above factors could be limited and other potential factors can be considered, such as prevention and control policies for COVID-19, time and spatial variation, etc. The prolonged online study duration and focus on electronic displays could be key factors affecting the "physical-psychological" well-being of college students, such as eye strain, which is more critical for under-age students. Future research could study the impacts of electronic screen size and provide coping strategies for online learning.

Besides, the built environment quality, e.g., temperature, humidity, acoustics, air pollutant, can influence the study performance (Tleuken et al., 2022). This study focuses on the general learning environment, and the effects of indoor built environment quality will be studies in the future. It should be noted that the suggestions in Section 4.4 are more from student side. As the online learning is a process involving multiple sides (e.g., teachers, students, schools and parents), the efforts and coping strategies from different sides should be composited for a more comprehensive solution which will be a future research.

5. Conclusions

Higher education is essential for knowledge transmission, technology innovation and sustainable development of society. While COVID-19 has transformed the traditional face-to-face education to be online learning, higher education has faced with new challenges and opportunities. This study conducts an online questionnaire survey that covers the majority of Chinese provinces or municipalities (30 out of 34), various majors and different universities. Main findings and conclusions are summarized as follows:

- The surveyed result indicates that, compared with senior students, online learning pattern is more likely to reduce the academic performance of lower-grade students (freshman and sophomore). The possible contribution factors are: duration of online learning (e.g., lasting more than 29 days) and frequency of having physical issues (e.g., eyestrain). Besides, the age of students could be one possible reason. Thus, it is recommended to design a hierarchical arrangement of online learning program customized for different grades based on their characteristics, e.g., flexible class duration, regular exercise, promoting paper-based courseware or learning.
- The learning environment could be one of the essential factors affecting the academic performance. Studying at home or dormitory is more likely to lead to a decline in academic performance and efficiency. While this survey shows that the majority of university students studying at home (54.7%) and dormitory (33.3%), it is of great urgency to improve the academic performance of students in these kinds of environment during online learning. For instance, more interactions and class discussions can be promoted in online teaching and a virtual learning community could be established to create an energetic and cooperative peer learning environment.
- Regarding the health and mental issues, anxiety is the most prominent mental issue with a 66% of occurrence. Results also show that females are more likely correlated with physical and mental health problems than males in terms of eye strain, cervical stiffness and anxiety. The possible reason is the longer learning duration and more online learning experience of the investigated female students.

COVID-19 has changed the way and pattern of learning and teaching in higher education. Meanwhile, new problems have emerged regarding the online learning performance, physical and mental health of college students. It is suggested to pursue an effective and productive online learning to promote the higher education in post-pandemic era for a civilized society and sustainable development.

Declaration of Competing Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Appendix A: Correlation Analysis

Table A1, A2, A3, A4

Table A1
Correlation between subjective factors of online learning and learning effect (r is correlation coefficient; p is significance level).

		Difficulty of online learning	Academic performance	Knowledge mastery
Daily Internet Entertainment Hours	r	-0.081*	-0.053	0.162**
	p	0.043	0.186	0.000
Attitude towards online learning	r	-0.317**	-0.455**	0.514**
	p	0.000	0.000	0.000
Eye strain	r	-0.134**	-0.192**	0.238**
	p	0.001	0.000	0.000
Cervical stiff	r	-0.127**	-0.164**	0.198**
	p	0.002	0.000	0.000
Dizziness and headache	r	-0.143**	-0.225**	0.212**
	p	0.000	0.000	0.000
Sleeplessness	r	-0.145**	-0.199**	0.155**
	p	0.000	0.000	0.000
Anxiety	r	-0.251**	-0.334**	0.329**
	p	0.000	0.000	0.000
Panic	r	-0.226**	-0.315**	0.297**
	p	0.000	0.000	0.000
Down	r	-0.204**	-0.278**	0.271**
	p	0.000	0.000	0.000
Emptiness	r	-0.219**	-0.294**	0.279**
	p	0.000	0.000	0.000

*$p < 0.05$ ** $p < 0.01$

Table A2
Correlation between objective factors of online learning and learning effect (r is correlation coefficient; p is significance level).

		Difficulty of online learning	Academic performance	Knowledge mastery
Grade	r	0.174**	0.173**	-0.197**
	p	0.000	0.000	0.000
Gender	r	0.046	0.035	0.025
	p	0.258	0.381	0.528
Major	r	0.123**	0.052	-0.107**
	p	0.002	0.201	0.008
Online Learning Experience	r	0.066	0.032	-0.093*
	p	0.100	0.432	0.021
Duration of the most recent online lesson	r	-0.101*	-0.130**	0.125**
	p	0.012	0.001	0.002
Online Learning Environment	r	0.182**	0.184**	-0.154**
	p	0.000	0.000	0.000
Teaching method	r	0.128**	0.011	0.012
	p	0.001	0.781	0.766

*$p < 0.05$ ** $p < 0.01$

Table A3
Correlation between grade, gender, online learning environment, preference for online learning and physical and mental health (r is correlation coefficient; p is significance level).

		Grade	Gender	Online Learning Environment	Attitude towardsonline learning
Eye strain	r	0.292*	0.048	0.075	0.321*
	p	0.039	0.738	0.604	0.023
Cervical stiff	r	0.086	0.188	0.163	0.245
	p	0.552	0.192	0.258	0.086
Dizziness and headache	r	0.056	0.109	0.202	0.241
	p	0.700	0.450	0.159	0.092
Sleeplessness	r	0.013	0.088	0.122	0.197
	p	0.930	0.544	0.400	0.171
Anxiety	r	-0.012	0.285*	0.085	0.314*
	p	0.935	0.045	0.557	0.027
Panic	r	0.038	0.013	0.064	0.336*
	p	0.795	0.928	0.660	0.017
Down	r	0.017	0.179	0.142	0.308*
	p	0.905	0.212	0.324	0.030
Emptiness	r	-0.084	0.143	0.170	0.306*
	p	0.560	0.320	0.239	0.030

*$p < 0.05$ ** $p < 0.01$

Note: In general, r>0.7 shows very close correlation, 0.4≤ r ≤0.7 shows close correlation, 0.2≤ r ≤0.4 shows regular correlation. A p-value less than 0.05 (and greater than 0.01) indicates that an event occurred with at least 95% certainty. A p-value of less than 0.01 means that an event occurred with at least 99% certainty. '*' mean the case of $p < 0.05$ is significant, while '**' means the case of $p < 0.01$ is significant. Based on Kolmogorov-Smirnov test, all the variables listed in Table A1-A3 could be considered as conforming to the normal distribution.

Table A4
Percentage of the most significant problem or difficulty encountered in online learning.

Problem description	Percentage
Inefficient learning	24.8%
Insufficient learning atmosphere	23.3%
Lack of learning support resources (no access to library, lack of textbooks, etc.)	13.0%
Problems not solved in a timely manner (e.g., lack of peer tutors, etc.)	7.7%
Lack of a quiet and independent learning environment	4.7%
Learning software platforms and network problems	4.2%
Easy to be distracted and difficult to focus on lectures	22.3%

Appendix B. Sample questionnaire

Questionnaire of online learning for college students during the epidemic

Q1. Grade
☐ Freshman ☐ Sophomore ☐ Junior ☐ Senior ☐ Master ☐ PhD student
Q2. Gender
☐ Male ☐ Female
Q3. What is your major category?
☐ Science, Engineering and Medicine
☐ Literature, History and Philosophy
☐ Economics and Management
☐ Law and Education
☐ Media and Arts
☐ Others:
Q4. Have you had any online learning experience before doing this questionnaire?
☐ More than 2 semesters ☐1 semester ☐ None before
Q5. How long has your most recent online class lasted?
☐ 1-7 days ☐ 8-14 days ☐ 15-21 days ☐ 22-28 days ☐ Over 29 days
Q6. What was your recent online learning environment?
☐ Home
☐ School dormitories
☐School classrooms and libraries
☐Graduate student studios and offices
☐ Others:
Q7. What was the teacher's teaching style in your recent online study?
☐ Most live broadcasts
☐ Equal frequency of live and recorded broadcasts
☐ Most recorded broadcasts
☐ Others:
Q8. Do you prefer online learning to traditional face-to-face teaching?
☐ Like very much
☐ Like somewhat
☐ Not sure (neutral)
☐ Dislike somewhat
☐ Dislike very much
Q9. How difficult do you find online learning compared to traditional face-to-face learning?
☐ Very hard
☐ Somewhat hard
☐ About the same degree of difficulty
☐ Somewhat simple
☐ Easy
Q10. Does online learning affect your performance compared to traditional face-to-face learning?
☐ Severe decline
☐ Definite decline
☐ None
☐ Definite upgrade
☐ Significant upgrade
Q11. How well did you master your knowledge during the online study?
☐ 90-100% (Proficient mastery)
☐ 80-90% (Good mastery)
☐ 70-80% (Better mastery)
☐ 60-70% (General mastery)
☐ 60% or less
Q12. How much time do you spend on Internet entertainment every day? (audio-visual entertainment, shopping, games, etc.)
☐ Within 2 hours
☐ 2-4 hours
☐ 4-6 hours
☐ 6-8 hours
☐ More than 8 hours
Q13. Please answer the following questions based on your physical condition during your online study.

(*continued*)

Eye strain: □Never □Once in a month □Once in a week □Once in 3 days □Every day
Cervical stiff: □Never □Once in a month □Once in a week □Once in 3 days □Every day
Dizziness and headache: □Never □Once in a month □Once in a week □Once in 3 days □Every day
Sleeplessness: □Never □Once in a month □Once in a week □Once in 3 days □Every day
Q14. Please answer the following questions based on your psychological situation during your online study.

Anxiety: □Never □Once in a month □Once in a week □Once in 3 days □Every day
Panic: □Never □Once in a month □Once in a week □Once in 3 days □Every day
Down: □Never □Once in a month □Once in a week □Once in 3 days □Every day
Emptiness: □Never □Once in a month □Once in a week □Once in 3 days □Every day
Q15. What is the most significant problem or difficulty you encountered during your online study? (Single-choice question)
□ Inefficient learning
□ Insufficient learning atmosphere
□ Lack of learning support resources (e.g., no access to library, lack of textbooks, etc.)
□ Problems not solved in a timely manner (e.g., lack of peer tutors, etc.)
□ Lack of a quiet and independent learning environment
□ Learning software platforms and network problems
□ Easy to be distracted and difficult to focus on lectures
Q16. Please select the city and region in your province:
Province:___ City:___ Region:___
Q17. Do you have any suggestions or comments about online learning and teaching? (Multiple Choice Questions)
□ Set up a variety of interactive classroom sessions and increase the frequency of interaction
□ Provide more learning materials, resources and platforms
□ Create the necessary classroom rituals (such as standing up, blackboard-writing)
□ Increase the frequency of classroom quizzes and homework feedback
□ Others:

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