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Research article

College students' satisfaction with online teaching during the COVID-19 pandemic: Evidence from Hubei Province, China

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ABSTRACT

To evaluate the performance of online teaching during the COVID-19 period, we collected 1886 survey data from college students in Hubei Province, China. The scoring rules of the Framework for Teaching were used to measure college students' satisfaction with online teaching, and an econometric model was constructed to empirically validate its dynamic influences. We found that college students' satisfaction with online teaching during the COVID-19 pandemic was lower than that with offline teaching. Online teaching satisfaction was significantly affected by variables of class size, proportion of online teaching, epidemic severity, college grade, network, course classification, major classification, and the teacher's age and skills. It was further found that as COVID-19 gradually dissipated, offline teaching should be resumed as soon as possible. These findings objectively evaluate the teaching performance of college students during the COVID-19 pandemic and can provide suggestions for optimizing online teaching during future emergencies.

1. Introduction

Online teaching has proven to be an important way to ensure that students can continue to receive education during the COVID-19 pandemic [1,2]. According to statistics from the United Nations Education Scientific and Cultural Organization (UNESCO), 90% of the world's students, or more than 1.6 billion people, experienced school closures and halts to teaching in March 2020, at a time when the COVID-19 pandemic was very serious.[1] UNESCO quickly mobilized governments, international organizations, and enterprises to form a global education alliance and advocated for continuity of education in 112 countries through online teaching. Among these countries, China has taken extreme measures to deal with the pandemic [3]. Data from China's Ministry of Education show that a total of 1454 universities across China have implemented online teaching programs. More than 0.95 million teachers and 1.18 billion students have been involved in online teaching until2022.[2] This shows that online teaching plays an important role in the teaching response to public health emergencies [4]. The COVID-19 epidemic is a global emergency. Therefore, this study aims to evaluate college students' satisfaction with online teaching during the COVID-19 epidemic, providing a reference for optimizing the quality of online teaching in future emergencies.

The evaluation of student satisfaction is key to characterizing the quality of online teaching [5,6]. However, there are not enough existing papers exploring the evaluation of online teaching during the COVID-19 pandemic, especially for Chinese students. This study

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[1] Detailed report can be found on the UNESCO website. https://www.unesco.org/en.

[2] More information can be obtained from the official website of Chinese Ministry of Education. http://www.moe.gov.cn/.

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collected student survey data from seven universities in Wuhan, Hubei Province, China, based on the special social context of the COVID-19 pandemic, and measured differences in online teaching satisfaction among college students with different characteristics using the Framework for Teaching (FFT) model. This work provides a variety of practical examples for objective evaluation of online teaching performance during the COVID-19 pandemic. Then, a linear regression estimation model was constructed to explore the factors affecting online teaching satisfaction. This work will undoubtedly provide guidance for addressing online teaching under other public health emergencies similar to COVID-19. This is important both for enhancing the continuity of school teaching and for ensuring educational accessibility for students during emergencies.

2. Literature review

Evaluation of online teaching satisfaction is an activity that judges the value of the teaching process and results based on teaching objectives and serves to guide teaching decision-making [7,8]. It is also a process of judging the real or potential value of teaching activities (i.e., teachers' teaching and students' learning) [9]. Overall, the value of the evaluation of students' satisfaction with online teaching is reflected as follows. First, the teaching effect should be evaluated comprehensively and objectively to understand all aspects of teaching and judge its quality, level, effectiveness, and defects [10]. The evaluation of teaching satisfaction, like physical examination, is a rigorous and scientific diagnosis of teaching [11]. Second, evaluation of teaching satisfaction can be used to monitor and strengthen teachers and students. The evaluation reflects the teaching effect of teachers and the learning achievements of students [12]. Teachers and students can revise and adjust the teaching plan according to the information received as feedback.

Scholars have demonstrated a wealth of measurement methods for assessing satisfaction with online teaching in normal circumstances (i.e., the absence of a public health emergency) [9,13]. Evaluation of teaching satisfaction can be measured by some single indicators in previous literature, such as final exam scores, classroom discipline, and student activity [14,15]. These indicators often focus more on improving academic performance based on the needs of students and parents. As education increasingly focuses on students' sustainable learning abilities, the indicators of teaching evaluation have been expanded to a multidimensional and comprehensive evaluation system including teachers, students, equipment, teaching content, and environment [16].

However, the performance of online teaching during the COVID-19 epidemic is rarely verified by scholars in China; although, many scholars have paid attention to the possible effects of the COVID-19 on students' attitudes and psychology towards online learning [2,10]. Some scholars have also attempted to conduct empirical analyses using student samples from Afghanistan [17], Sri Lanka [16], South Korea [5], and Malaysia [1]. However, online teaching during the COVID-19 pandemic is different from offline teaching and other distance education [18], and the Chinese sample is unique because of the strict school control policies implemented by the government [3], which can be seen below. First, during the three years that the spread of COVID-19 continued unabated, online teaching was a forced act of pedagogical adjustment rather than an option available to schools [9]. Second, the variability of COVID-19 means that it can cause repeated infections in students, but the high demand for offline teaching by students and their parents makes it possible to alternate between online and offline teaching of a course. These factors have greatly destroyed the stability of online teaching [19]. Third, COVID-19 affects students of all ages (elementary, middle school, high school, college, etc.) [20]. Therefore, it is necessary to re-measure online teaching satisfaction under the specific conditions of the COVID-19 pandemic in China.

This study makes two main contributions to literature. First, it differs from previous literature on the evaluation of satisfaction with traditional offline teaching and online teaching in the absence of a pandemic. That is, online teaching during the COVID-19 pandemic is typically mandatory, dynamic and extensive. This heterogeneity makes evaluation of online teaching during this period of particular value. Second, a linear regression estimation model was constructed to explore the factors affecting online teaching satisfaction in terms of the elemental components of online teaching dimensions, teachers, students, equipment, courses, and COVID-19. At the same time, a group estimation model was used to explore the dynamic impact of changes in the COVID-19 pandemic.

3. Materials and methods

3.1. Measurement of online teaching satisfaction

The basis of this research is the question of how to effectively measure students' evaluation of online teaching. We took as our model the Framework for Teaching (FFT), a classroom teaching evaluation framework developed by Professor Danielson of the American Educational Testing Service [21,22]. The FFT focuses on the overall quality of classroom teaching. It not only focuses on the quality of results (i.e., students' academic achievements), but also evaluates the quality of the background and process of teaching preparation, classroom environment building, and teachers' professional responsibilities [23]. That is, the FFT not only focuses on students' learning, cognition, and construction, but also on students' interests, emotions, and needs. Since the FFT was revised in 2013, this framework has become the most widely used measurement tool in the United States and subsequently in Canada, China, Japan, and other countries [24].

The FFT divides the complex work of teaching into four dimensions: planning and preparation, the online classroom environment, instruction, and professional responsibilities (Table 1). The surveyed students score the four dimensions of online teaching one by one. Scores 1–4 represent the degree of completion of different dimensions. Then, the comprehensive scores of students' satisfaction with online teaching can be summed up using the four dimension scores.

Table 1
Scoring rules for the Framework for Teaching (FFT).

	Teaching status corresponding to 1–4 scores			
	1	2	3	4
Planning and preparation	The teaching plan is unreasonable. Teachers are not familiar with the teaching content and students' characteristics. Inadequate teaching preparation. Inappropriate setting of teaching objectives. The evaluation method is not scientific.	The teaching plan is reasonable and teaching can be designed according to the teaching content and students' characteristics. The goal adapts to students, but it is difficult for some students. The evaluation method is suitable for most students.	The teaching plan is scientific and reasonable, fully adapted to the characteristics of students. Goal setting considers all students. The evaluation is consistent with the goal.	The teaching plan reflects teachers' deep understanding of students' characteristics and teaching content, aiming at making all students learn meaningfully. The objective is scientific and reasonable. The evaluation is consistent with the goal.
The online classroom environment	The online classroom environment is chaotic and noisy. Teachers have low expectations of students. The rules and regulations of behavior are not clear. Interpersonal interactions are negative.	The online classroom environment is relatively harmonious. Teachers have moderate expectations of students. The behavior rules and regulations are clear. Students and teachers respect each other.	The online classroom environment can promote students' learning. Teachers have high expectations of students. Interpersonal communication is based on mutual respect.	Students participate in the creation and maintenance of a good online classroom environment. There is a high level of interpersonal interaction. The teachers' high expectations are characteristic of the classroom environment.
Instruction	Only a few students participate in the class interaction. Teachers strictly abide by the teaching plan in teaching. There is little or no use of formative assessment.	Incomplete communication between teachers and students. Teaching activities do not involve all students. Teachers can adjust the teaching plan appropriately. Formative assessment used.	The communication between teachers and students is smooth. All students participate in learning. The effect of teaching activities is good. Evaluation can be effectively used to promote teaching.	All students actively participate in class activities. Teaching activities are suitable for all students. The needs of all students are met. Teaching is flexible and not rigid.
Professional responsibilities	Teachers' behavior does not reflect professional ethics and professionalism. The teacher does not reflect after class, does not communicate with colleagues, and does not participate in teaching and research activities.	Teachers' behavior reflects some professional ethics and professionalism. Teachers keep moderate communication with parents and colleagues and are able to participate in teaching and research activities.	Teachers strictly abide by professional ethics. Teachers often reflect on teaching, actively communicate with parents and colleagues, and actively participate in teaching and research activities.	Teachers strictly abide by professional ethics. The communication between teachers, parents, and colleagues is positive and effective. Teachers actively participate in and organize teaching and research activities.

Notes: The measurement method of this table comes from the research of Zhang and Yang [24].

3.2. Framework of influencing factors of online teaching satisfaction

In order to better explore the important factors that influence students' online teaching satisfaction evaluation in reality, we need to build an analysis framework. We know that the constituent elements are the key to the stable and efficient functioning of online teaching systems [4,25]. Based on element composition theory, the basic components of online teaching evaluation include the teacher, students, course, and equipment [1,26]. In addition, we further consider the COVID-19 pandemic as a non-negligible factor. These constituent elements may directly affect students' satisfaction with online teaching (Fig. 1).

Teachers are the most important teaching body in universities, and the source of knowledge transmission. Teachers are the implementers of educational purposes and the designers of educational activities [10,27]. Student learning depends on the guidance and direction of teachers, and teaching practices play a major role in the effectiveness of learning. Different teachers have different teaching abilities and styles [25]. Therefore, the overall quality of teachers will directly affect the ultimate learning outcomes of students. For example, studies have shown that a teacher's age and title affect their accumulated teaching skills and subsequently affect teaching performance [13]. In general, teachers with older age and higher titles tend to have better teaching ability and thus higher student satisfaction [16,21]. In addition, online teaching is different from traditional offline teaching, in that teachers need to use the computer for extended periods to display teaching content, so the proficiency of computer operation will affect the fluency of the entire online teaching display [11].

Students are the recipients of knowledge, and their learning is key to determining the outcome of teaching satisfaction. The need to pay attention to students' individual differences in teaching has long been a key component of teaching reform. Thus, student heterogeneity is an important factor affecting teaching satisfaction. Many studies have shown that teaching styles should be diverse, meaning that different students are suited to different learning styles [19,24]. Therefore, different students approach online teaching with different preferences [17]. For example, students of different genders have different learning habits and learning style preferences [1]. Student learning performance also varies widely across class sizes: the smaller the class size, the better the teaching results [28]. Importantly, there are differences in the way students approach learning at different grade levels [10]. Compared to offline teaching, online teaching is freer in terms of space and is not confined to a small classroom.

The course is the object of online teaching. Learning difficulties and teaching content vary widely from one course to another, resulting in differences in online teaching satisfaction [29]. Teachers should differentiate teaching according to course content to meet the individual needs of different students. For example, natural science and social science courses are very different [16]. Natural science courses such as physics and chemistry rely more on experiments, equipment, and practice, while social sciences such as history, literature, and art can be clearly expressed through pictures and text, etc. It is important to note that the online teaching of practical classes is currently very challenging [13], as is the case with courses such as physical education, course internships, and practical simulation. In addition, the different proportions of time allocated between teaching online and offline in a hybrid course will affect the design and effectiveness of the entire course [15].

Equipment is an essential element to support online teaching and learning. Some studies have shown that teaching equipment significantly affects the efficiency and effectiveness of online teaching [4]. On the one hand, online teaching relies on hardware

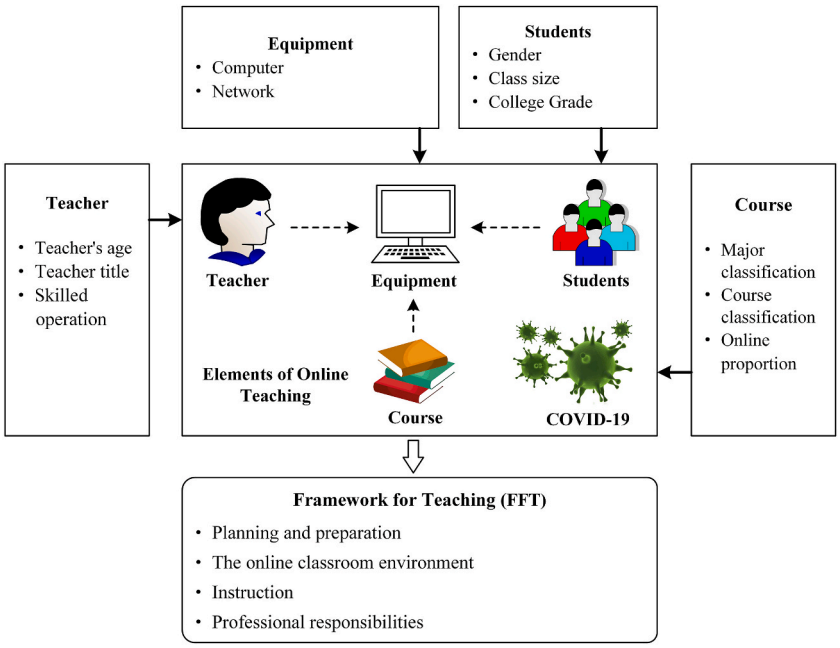

Fig. 1. FFT of online teaching and its influencing factors.

equipment such as computers or mobile phones [1]. This is because teachers need to use computers to display powerpoint content in teaching. Students also need to use network reception equipment to watch and learn from these online materials. On the other hand, software facilities are also important, as reliable network video and voice are the basic guarantees of online teaching. Live online courses must be supported by a reliable network [19]. Network delays and disconnections not only affect the continuity of teacher instruction, but also disrupt the learning process of students.

COVID-19 is an important factor restricting offline teaching and initiating an uprise in online teaching. The epidemic has changed the social environment of online teaching, making the motivation of teachers' teaching and students' learning different [30]. COVID-19 is extremely infectious and harmful to health and has forced a halt to offline teaching and a start to online teaching [18]. For example, the Chinese government was highly concerned about COVID-19. Once the severity of the epidemic increased, schools were immediately forced to replace offline teaching with online teaching [3].

3.3. Data sources

China's Hubei Province is an important representative region of the COVID-19 pandemic, as its central city of Wuhan is one of the first cities where the COVID-19 epidemic was observed [11]. In October 2020, our research team conducted an e-questionnaire survey of undergraduate students at 12 key universities in Wuhan, Hubei Province, China (Table 2). The design of the questionnaire was subject to continuous discussion and revision by the research team and was submitted to scholars in related fields for review; the final draft was developed in August 2020. Then, a pre-survey was conducted at the Wuhan Institute of Technology, while the questionnaire was continuously adjusted and optimized. The content of the questionnaire focused on collecting information on learning styles, learning effectiveness, and teaching satisfaction during the COVID-19 pandemic. A stratified random sample was taken by each school and the e-questionnaires were forwarded to the academic offices of the different schools and sent to university students by the teaching secretaries. Finally, the research team eliminated invalid questionnaires with missing data. In this survey, we distributed a total of 2000 questionnaires. Among them, 1913 questionnaires were collected, 27 were excluded after sorting, and finally 1886 valid questionnaires were obtained. The distribution characteristics of the sample college students (Table 2) meet the stratified sampling requirements and indicate that the data are suitable for further analysis.

3.4. Model

Considering that the dependent variable was a continuous variable with a value range of 1–16, we constructed a linear regression econometric model to verify the important factors influencing college students' satisfaction with online courses.

$$FFT_i = \beta_0 + \beta_1 Student_i + \beta_2 Teacher_i + \beta_3 Course_i + \beta_4 Equipment_i + \beta_i COVID19_i + \mu_i \quad (1)$$

where FFT_i in Equation (1) is the online course satisfaction score of the ith student. *Student* are the variables related to the college students (gender, class size, and college grade) [17]. *Teacher* are the variables associated with the teacher (teacher's age, teacher title, and skilled operation) [11]. *Course* are the variables associated with the course (major classification, course classification, online proportion) [16]. *Equipment* are the variables that ensure the smooth running of the online course (computer, network) [4]. *COVID-19* is a variable representing the severity of the epidemic, which can be measured by the ratio of COVID-19 patients in the respondent's residential quarters over the past week. This ratio is calculated by dividing the new population infected with COVID-19 by the total population of the community. This data is derived from publicly available data records from the interviewee's community.[3] β_i is the coefficient of the linear regression model to be estimated. μ is the random error term. Based on the significance of β_i, we can determine which factors affect the *FFT*, and the positive or negative regression coefficients of the variables can be determined the positive and negative effects from these factors. The specific information on the variables in the model is shown in Table 3.

4. Results

4.1. Statistical analysis of online and offline teaching satisfaction

We used the scale presented in Table 1 to statistically analyze the sample data, and the results shown in Fig. 2 indicate that there is a difference between online and offline teaching satisfaction among college students. First, the average cumulative score of offline teaching satisfaction among college students was 10.92, which was higher than the online teaching satisfaction score of 9.86. Second, the mean scores of planning and preparation, the online classroom environment, and professional responsibility in offline teaching satisfaction measures were all higher than those for online teaching, while only instruction had a slight advantage in online teaching satisfaction.

Compared to offline teaching, students generally have lower satisfaction with online teaching. There may be many reasons for this from previous literature: First, the lag in online teaching equipment and technology has affected the effectiveness of online teaching [11]. There is no guarantee that every college student in China has excellent computer equipment and sufficient network capacity

[3] This data was registered and published daily by the Health Commission of Hubei Province. http://wjw.hubei.gov.cn/bmdt/ztzl/fkxxgzbdgrfyyq/xxfb/index_1.shtml.

Table 2
Distribution statistics of sample college students.

Categories	Options	Number	Percentage (%)
Gender	Male	982	52.07
	Female	904	47.93
College grade	Freshman	537	28.47
	Sophomore	491	26.03
	Junior	472	25.03
	Senior	386	20.47
School	Wuhan University	162	8.59
	Huazhong University of Science and Technology	148	7.85
	Huazhong Normal University	151	8.01
	Huazhong Agricultural University	160	8.48
	China University of Geosciences	149	7.90
	Wuhan University of Technology	141	7.48
	Zhongnan University of Economics and Law	150	7.95
	Hubei University	147	7.79
	South-central University For Nationalities	153	8.11
	Wuhan Institute of Technology	205	10.87
	Hubei University of Technology	161	8.54
	Wuhan University of Science and Technology	159	8.43

Notes: Only undergraduate students, not graduate students, were included in this study.

Table 3
Definition and statistics of variables in the model.

Independent variables	Definitions and assignments	Mean	S.D.
Female (Male)	1 if the interviewee is female, 0 otherwise.	0.425	0.107
Small class (Large class)	1 if the number of students in the class is less than 30, 0 otherwise.	0.319	0.186
College grade (Freshmen)			
Sophomore	1 if the interviewee is sophomore, 0 otherwise.	0.215	0.126
Junior	1 if the interviewee is junior, 0 otherwise.	0.198	0.177
Senior	1 if the interviewee is senior, 0 otherwise.	0.207	0.130
Computer (Not computer)	1 if the interviewee uses a computer for online courses, 0 otherwise.	0.789	0.242
Network (No network)	1 if the interviewee uses a wired network to access the online courses, 0 otherwise.	0.356	0.415
Social Science (Natural Science)	1 if the course teaching online is in the social sciences, 0 otherwise.	0.420	0.237
Course classification (Professional)			
Public	1 if the course teaching online is in the public category, 0 otherwise.	0.168	0.264
Elective	1 if the course teaching online is in the elective category, 0 otherwise.	0.347	0.196
Practical	1 if the course teaching online is in the practical category, 0 otherwise.	0.095	0.422
Online proportion (0–25%)			
26%–50%	1 if the hourly ratio of online teaching is 26–50 percent, 0 otherwise.	0.126	0.548
51%–75%	1 if the hourly ratio of online teaching is 51–75 percent, 0 otherwise.	0.237	0.403
76%–100%	1 if the hourly ratio of online teaching is 76–100 percent, 0 otherwise.	0.510	0.281
Teacher's age (Under 30 years old)			
30–45 years old	1 if the age of the teacher teaching online is 30–45 years old, 0 otherwise.	0.319	0.217
46–60 years old	1 if the age of the teacher teaching online is 46–60 years old, 0 otherwise.	0.582	0.132
Teacher title (Lecturer)			
Associate professor	1 if the teacher teaching online is associate professor, 0 otherwise.	0.516	0.209
Professor	1 if the teacher teaching online is professor, 0 otherwise.	0.248	0.316
Skilled operation (Not skilled)	1 if teacher has the ability to operate online learning equipment (e.g., computers), 0 otherwise.	0.322	0.425
Epidemic severity	The ratio of COVID-19 patients in the respondent's residential quarters over the past week.	0.104	0.216

Notes: The natural sciences include the basic sciences of physics, chemistry, biology, astronomy, and earth science, as well as applied sciences such as medicine, agriculture, meteorology, and materials science. Social science mainly refers to economics, politics, law, ethics, history, sociology, psychology, pedagogy, management, etc. Reference variables in parentheses.

during the COVID-19 pandemic [20]. For example, a large number of samples reported that large crowds of people logged on to e-learning at the same time, resulting in web page overload and unstable networks. Second, online learning relies heavily on students' self-motivation, and course quality is difficult to monitor [9]. Whether students listen attentively or not cannot be accurately assessed. Some college students even admit to watching videos, playing games, or eating snacks during online courses. Some studies also indicate that students are easily disturbed by the outside environment in a non-classroom setting and have difficulty concentrating on the lecture [16,29]. In addition, students are prone to burnout due to visual fatigue from looking at slides for long periods of time [6]. Third, online teaching separates students from teachers in time and space, making it more difficult for teachers' home visits and course feedback [31]. COVID-19 control measures limited travel activities between teachers and students [4], and most communication between teachers and students' parents was limited to phone calls [14]. There were also very few opportunities for students to participate in the design and revision of course content. During the online teaching process, except for the feedback in the form of pop-up text, the teacher cannot see the students' messages through their bodies, expressions, eyes, etc. In most cases, teachers have to

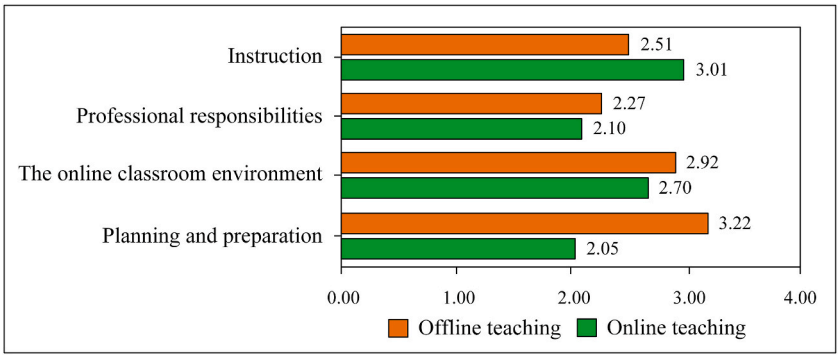

Fig. 2. Differences in samples' satisfaction with online and offline teaching.

teach at their own pace.

Of course, online teaching also has certain unique advantages in terms of student instruction. Simple online teaching activities can be carried out with just a cell phone or computer, greatly improving the feasibility of continuing education activities during emergencies [12]. More diverse teaching materials such as text, data, photos, audio, and video can be used simultaneously in online teaching to support classroom instruction [32]. In addition, students can watch the recorded teaching video repeatedly. They have different choices in terms of learning time and style. These will profoundly change the way learners seek knowledge [15]. There is no doubt that online education can encourage students to form habits such as online learning, continuous learning, and independent learning, and enhance their learning abilities. Students can also quickly submit teaching evaluation information via web and electronic questionnaires. There is no denying that the online teaching platform enhances the ease of attendance and submission of assignments and provides technology for high-quality student participation in the classroom [20].

4.2. Online teaching satisfaction among different groups

The independent sample T-test was used to determine significant differences between groups of college students. The results can be seen in Table 4. These results show that: First, among the sample of college students of different grades, seniors had the highest online teaching satisfaction score of 11.67, freshmen had the lowest satisfaction score of 5.81, and sophomores and juniors were in the middle. Online teaching satisfaction for small classes was 9.92, higher than the 6.37 score for large classes. The above results can be explained by the information reflected in the research sample. For example, freshmen students generally reported that they were not comfortable with online teaching. Most of the students in the sample of large classes felt that they did not receive sufficient attention from their teachers. Second, there was heterogeneity in the scores for the different course classifications. Professional courses had the highest score of 10.15, followed by elective courses and public courses, while practical courses had the lowest score of 5.60. Similarly, the online teaching satisfaction score for college students in the social sciences in the professional classification was 9.72, higher than the score of 8.24 for the natural sciences. This is mainly because different courses are adapted to different delivery methods, and many practical courses and natural science experiments cannot be performed through a computer screen. Third, middle-aged teachers aged

Table 4
FFT scores of college students in different groups.

Index	Categories	FFT score mean	*t*-value	p-value
College grade	Freshmen	5.81	2.06	0.032
	Sophomore	8.56		
	Junior	8.02		
	Senior	11.67		
Class size	Large class	6.37	2.78	0.009
	Small class	9.92		
Course classification	Professional	10.15	2.13	0.037
	Public	7.13		
	Elective	8.72		
	Practical	5.60		
Major classification	Social science	9.72	1.84	0.057
	Natural science	8.24		
Teacher's age	Under 30 years old	7.86	1.91	0.051
	30–45 years old	10.53		
	46–60 years old	9.05		
Online proportion	0–25%	4.68	2.29	0.044
	26%–50%	9.91		
	51%–75%	8.76		
	76%–100%	7.90		

30–45 had the highest online teaching satisfaction score of 10.53, while younger and older teachers had lower scores. In addition, the weighting of time allocated between online and offline teaching for the same course also resulted in differences in course satisfaction, showing that samples with a moderate online teaching share of 26%–75% scored higher than those with 0–25% and 76%–100% samples. This shows that a moderate combination of online and offline teaching methods was preferred by students.

4.3. Estimation of the influencing factors of online teaching satisfaction

We used Stata software to estimate the coefficients of Equation (1). First, the collinearity between independent variables was verified to avoid bias in model estimation results. Second, the model's *F*-value was 11.175 and thus passed the 1% significance threshold. This indicates that the overall fit of the model is good and the estimation results are stable. Finally, further judgments can then be made based on the significance of the estimated coefficients of the variables in Table 5. If a coefficient passes the significance test, that means it is a factor influencing online teaching satisfaction, and if it does not pass the significance test, then it is not. At the same time, we can interpret the above measurement results by combining the actual information reflected by the samples and the previous literature.

The coefficients of the effects of these variables — small class, 26–50% proportion of online teaching, and epidemic severity — on online teaching satisfaction passed the 1% significance level test and had a positive effect direction. Specifically, smaller class sizes were associated with higher satisfaction with online teaching. This is mainly because large classes divert teachers' efforts. Liang and Fung [28] also pointed out that teachers can only devote themselves to a small number of students in a limited amount of time. As a result, students in smaller classes are guaranteed interaction with their teachers, and the quality of their instruction will improve accordingly. The 26–50% proportion of online teaching led to a significant increase in online teaching satisfaction, while the 51–75% proportion of online teaching also passed the 5% significance test. This shows that a moderate combination of online and offline teaching can effectively improve online teaching satisfaction. By contrast, if the time allocated for online teaching is too short, students are not fully adapted to the online learning environment, resulting in poorer results [16]. If the time allocated for online teaching is too long, the practical part of the course will be poorly experienced [4]. Online teaching satisfaction decreased as the severity of the epidemic decreased. A possible reason for this is that the government education department would adjust the corresponding course teaching plan, disrupting students' learning plans and leading to unstable learning expectations in the short term [9]. In addition, some scholars believe that the lack of immediate recovery of students' physical health in the short term is also an important factor leading to a decrease in satisfaction with online teaching [6].

Table 5
Regression estimation results of the influencing factors of online teaching satisfaction.

Independent variables	Dependent variable: FFT scores			
	Coef.	S.E.	t-value	p-value
Female (Male)	−0.025	0.373	−0.071	0.947
Small class (Large class)	0.998***	0.288	3.465	0.001
College grade (Freshmen)				
Sophomore	0.171	0.206	0.830	0.408
Junior	0.422	0.615	0.686	0.491
Senior	1.433**	0.725	1.976	0.048
Computer (Not computer)	0.243	0.401	0.615	0.545
Network (No network)	1.707**	0.699	2.442	0.015
Social Science (Natural Science)	0.313*	0.164	1.908	0.057
Course classification (Professional)				
Public	−0.281	0.329	−0.854	0.395
Elective	−0.011	0.064	−0.172	0.864
Practical	−0.195**	0.097	−2.010	0.045
Online proportion (0–25%)				
26%–50%	0.893***	0.257	3.475	0.001
51%–75%	0.083**	0.034	2.441	0.014
76%–100%	0.003	0.008	0.363	0.719
Teacher's age (Under 30 years old)				
30–45 years old	0.380**	0.183	2.077	0.038
46–60 years old	0.213	0.177	1.203	0.228
Teacher title (Lecturer)				
Associate professor	0.142	0.158	0.907	0.369
Professor	0.042	0.159	0.265	0.793
Skilled operation (Not skilled)	0.002**	0.001	2.160	0.031
Epidemic severity	0.432***	0.165	2.618	0.009
Constant	−0.139	1.022	−0.141	0.892
F-Value	11.175***			
Adj R-squared	0.125			
Number of observations	1886			

Notes: *, **, and *** represent the estimated coefficients of the variables passing the significance level test at the 10%, 5%, and 1% levels, respectively. The reference system is in parentheses.

The positive effect of the variable "senior" on student satisfaction with online teaching passes the 5% significance level test. Seniors' high satisfaction with online teaching is due to the pressure of their thesis and job search, and their greater desire to earn credits by taking classes in a more flexible manner [20]. In contrast, freshmen who have just graduated from high school prefer traditional offline teaching modes [19]. The positive effect of the variable "network" on student satisfaction with online teaching passes the 5% significance level test. Network is a necessary facility for students to access online classes at home. Network expands the time and space available for students to study online courses and is a guarantee of the smooth progress of online courses [15]. Students in homes without a network can only access online classes through the limited bandwidth of their cell phones. The positive effect of the variable "skilled operation" on student satisfaction with online teaching passes the 5% significance level test. Teachers' proficiency in computer software affects the presentation of online instruction [11].

The negative effect of the variable "practical" on student satisfaction with online teaching passes the 5% significance level test. Professional courses are the core mission of teaching and learning, and teachers will put more time and effort into preparing for them. However, there are huge challenges in teaching practical courses online, where teachers and students can only work across the screen and perform physical activities with limited content and space in front of the computer [13]. The negative effect of the variable "30–45 years old" on student satisfaction with online teaching passes the 5% significance level test. Compared to younger and older teachers, middle-aged teachers have accumulated teaching experience and teaching energy, and tend to have more motivation to make good online courses and receive higher online teaching evaluations [33]. Finally, the coefficient of influence of social science on online teaching satisfaction passed the 10% significance level test and the direction of influence was positive. This is mainly due to differences in learning styles across disciplines. For example, some scholars have indicated that undergraduate courses in the natural sciences tend to rely on more hands-on processes such as lab work, visual effects, and mechanical design, which are not feasible in online teaching [16,29].

4.4. Online teaching during the gradual decline of COVID-19

As the global COVID-19 epidemic is improving, we ran a simulation to explore the dynamics of factors influencing online teaching satisfaction ratings after a continuous decrease in the stringency of epidemic control. We ranked the epidemic severity indicators from smallest to largest and divided the total sample into three subsamples from 1/3 and 2/3 nodes according to the principle of equal sampling: low level, medium level, and high level, where higher levels indicated a more severe epidemic and a higher probability of restricting student travel. Using Equation (1) to estimate subsamples in groups gave the results shown in Table 6.

Comparing the three groups of estimates shows that, first, the effect of college grades on online teaching satisfaction will diminish as the severity of the epidemic increases. Because the freedom of movement of all students is restricted when the epidemic is very severe, the urgency of finding a job decreases for senior students. Second, at a low level of epidemic severity, the negative impact of lack of network access will be diminished. At such a time, students can seek better public network resources to conduct online course learning. Third, with a decline in the severity of the epidemic, the lower the proportion of online teaching, the higher the satisfaction. That is, students prefer offline teaching methods when there is no epidemic. Similarly, online learning seems to be a forced choice for students under severe epidemic control. During the survey, it was also found that under the situation of the long-term epidemic and

Table 6
Regression estimation results of the influencing factors of online teaching satisfaction.

Independent variables	Dependent variable: FFT scores											
	Low level of epidemic severity				Medium level of epidemic severity				High level of epidemic severity			
	Coef.	S.E.	t-value	p-value	Coef.	S.E.	t-value	p-value	Coef.	S.E.	t-value	p-value
Small class (Large class)	0.303***	0.104	2.913	0.004	0.627***	0.172	3.645	0.005	0.019***	0.005	4.021	0.004
College grade (Freshmen)												
Senior	1.327***	0.334	3.973	0.001	0.271*	0.163	1.663	0.097	0.144	0.169	0.852	0.395
Network (No network)	0.112	0.169	0.663	0.508	0.546**	0.276	1.978	0.048	2.231**	0.893	2.498	0.013
Social Science (Natural Science)	0.003*	0.002	1.831	0.067	0.069*	0.036	1.917	0.057	0.153*	0.086	1.779	0.077
Course classification (Professional)												
Practical	0.368**	0.164	2.244	0.025	0.001**	0.001	2.070	0.039	1.373**	0.544	2.524	0.012
Online proportion (0–25%)												
26%–50%	−2.154**	1.011	−2.131	0.033	0.004*	0.002	1.688	0.093	0.107**	0.045	2.367	0.019
51%–75%	−0.130*	0.073	−1.781	0.074	0.103*	0.053	1.943	0.053	0.129*	0.073	1.767	0.078
Teacher's age (Under 30 years old)												
30–45 years old	0.129*	0.073	1.767	0.078	0.169	0.098	1.724	0.084	0.988**	0.432	2.285	0.022
Skilled operation (Not skilled)	0.006**	0.003	2.276	0.024	1.072**	0.451	2.377	0.018	0.033**	0.014	2.460	0.014
F-Value	9.521***				10.584***				7.175***			
Adj R-squared	0.086				0.073				0.071			
Number of observations	629				628				628			

Notes: *, **, and *** represent the estimated coefficients of the variables passing the significance level test at the 10%, 5%, and 1% levels, respectively. The reference system is in parentheses. Non-significant variables are not presented in this table.

restricted freedom of movement, students were eager for a free way of life and learning [12], and they were very much looking forward to meeting their classmates [10]. As the epidemic gradually dissipates, it becomes very necessary to resume offline teaching as soon as possible [6].

Importantly, the significance of these variables, such as small class, social science, practical course, 30–45 years old teachers, and skilled operation, does not change with the severity of the epidemic. These are factors that need to be improved in conventional online teaching. Similar results have also been observed by scholars such as Yu et al. [11], Liang and Fung [28]. In the future, online teaching should adopt medium-sized classes. At the same time, online teaching should pay attention to the differences between the teaching methods of the social sciences and the natural sciences, as well as the differences between professional and practical courses. We should explore different teaching methods to meet the needs of students [29]. Finally, it is necessary to strengthen the training of teachers' online teaching skills [34], so that teachers can use information teaching tools and thus improve students' satisfaction with online teaching.

5. Discussion

Previous literature on online courses or e-education cannot accurately reflect the characteristics of online teaching during the COVID-19 pandemic. This study also obtained some valuable conclusions, which differ from previous literature [12,20]. For example, we found that the evaluation of online teaching is not ideal, and is lower than that of offline teaching. There is no doubt that online teaching and offline teaching have their advantages and disadvantages [2,5]. The purpose of this study is to provide useful references for evaluating and optimizing online teaching in emergencies, rather than to state that offline teaching has absolute advantages over online teaching. College students in Hubei Province, China, were selected to conduct research on online teaching satisfaction evaluation during the COVID-19 pandemic in this study. Although there are limitations in the distribution of the sample area and the COVID-19 pandemic context, it can still provide practical experience for improving the quality of online teaching for college students in future emergencies. Of course, the global development of digital teaching is accelerating, but there are still many countries and regions that do not know how to carry out effective online teaching activities [9,34]. Therefore, future research should focus more on topics such as successful models, system optimization, teacher training, and dynamic adjustment of online teaching.

6. Conclusions

Based on survey data, this study used the Scoring rules of the Framework for Teaching (FFT) to measure online teaching satisfaction of college students in Hubei Province during the COVID-19 pandemic. In the theoretical framework of student, teacher, course, equipment, and COVID-19, we used Stata software to build a linear econometric model to explore the influencing factors of online teaching satisfaction. The main findings of the study are as follows:

First, college students' satisfaction with offline teaching was higher than that of online teaching during the COVID-19 pandemic. We also found that online teaching satisfaction was higher in the following groups: senior, small class, professional course, social science, middle-aged teacher, and 26–75% of online teaching. Based on the above findings, we can derive some policy implications. That is, online teaching is really one of the most important ways to continue education in the event of an emergency. However, our sample shows that the performance of online teaching has not been entirely satisfactory. Therefore, it is still very necessary to strengthen the systematic construction of online teaching to ensure the quality of students' education during future emergencies. Most teachers are inexperienced during the epidemic because they are teaching online for the first time. So, universities should encourage teachers to boldly explore new teaching scenarios, use high-tech teaching tools, and experiment with new teaching models in general.

Second, online teaching satisfaction can be affected by these variables: small class, 26–50% proportion of online teaching, social science, epidemic severity, senior, Wi-Fi, practice class, 31–45 years old, and skilled operation. Based on the above findings, we can draw some policy implications. That is, we can continuously adjust the environment and conditions of online teaching for students and optimize online teaching performance. For example, classes with too many students should be split. The allocation of class time between online and offline teaching needs to be adjusted appropriately. Schools need to offer heterogeneous online teaching to fully respect the variability of different grades, courses, and professional categories. For example, in the future process of online teaching reform, we should focus on the teaching preferences of freshmen and actively explore online teaching methods for practical courses. Skills training for digital teaching should be emphasized more by schools. Of course, in the event of an emergency similar to the COVID-19 pandemic, government departments can also exempt or reduce network fees for student groups, or open exclusive education network channels.

Third, this study found that the impact of the network on online teaching satisfaction will be weakened with the decline of the severity of the COVID-19 pandemic, while the impact of college grades will increase. Offline teaching should be resumed as soon as possible to meet the teaching needs of students after the emergency event resumes. Based on the above findings, we can derive some policy implications. Having suffered restrictions and separation for a long time, college students are now eager to get out and go to the classroom to meet classmates and teachers. However, schools still need to pay attention to class size, course, and professional heterogeneity of teaching and teacher skills training, even if online teaching is conducted in a conventional (no COVID-19) situation. Predictably, changes in educational models in the post-epidemic era will require constant error correction at the practice level and dynamic adjustments along the way.

Limitations

Of course, these findings have some limitations: First, these conclusions may not necessarily apply to online course evaluation in non-emergency situations. Students are forced to participate in the online teaching and learning process during the COVID-19 epidemic. However, in the digitalization of teaching, it is more about going for student-initiated online teaching needs. Second, the heterogeneity of different countries' attitudes to the COVID-19 epidemic will also limit extension of the research conclusions to other countries. Similarly, the infrastructure for online teaching varies from country to country. Therefore, there is a need for further validation of students' satisfaction with online teaching in different contexts and countries.

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Data availability statement

Data will be made available on request.

Ethics statement

This study was reviewed and approved by Wuhan Institute of Technology Research Ethics Committee, with the approval number 202008165. All respondents in the study completed the questionnaire with their consent sought.

CRediT authorship contribution statement

Yanzhong Huang: Writing – review & editing, Writing – original draft, Software, Methodology, Funding acquisition, Conceptualization. **Zhongbo Xiong:** Visualization, Methodology, Data curation. **Di Liu:** Writing – review & editing, Writing – original draft, Investigation, Data curation. **Yan Zhang:** Writing – review & editing, Resources, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e28579.

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