Students' Experience of Online Learning During the COVID-19 Pandemic: A Province-wide Survey Study

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ABSTRACT

Online learning is currently adopted by educational institutions worldwide to provide students with ongoing education during the COVID-19 pandemic. Even though online learning research has been advancing in uncovering student experiences in various settings (i.e., tertiary, adult, and professional education), very little progress has been achieved in understanding the experience of the K-12 student population, especially when narrowed down to different school-year segments (i.e., primary and secondary school students). This study explores how students at different stages of their K-12 education reacted to the mandatory full-time online learning during the COVID-19 pandemic. For this purpose, we conducted a province-wide survey study in which the online learning experience of 1,170,769 Chinese students was collected from the [Anonymous] Province of China. We performed cross-tabulation and Chi-square analysis to compare students' online learning conditions, experiences, and expectations. Results from this survey study provide evidence that students' online learning experiences are significantly different across school years. Foremost, policy implications were made to advise government authorizes and schools on improving the delivery of online learning, and potential directions were identified for future research into K-12 online learning.

1. Introduction

The ongoing COVID-19 pandemic poses significant challenges to the global education system. By July 2020, the UN Educational, Scientific and Cultural Organization (2020) reported nation-wide school closure in 111 countries, affecting over 1.07 billion students, which is around 61 percent of the global student population. Traditional brick-and-mortar schools are forced to transform into full-time virtual schools to provide students with ongoing education (Van Lancker & Parolin, 2020). Consequently, students must adapt to the transition from face-to-face learning to fully remote online learning, where synchronous video conferences, social media, and asynchronous discussion forums become their primary venues for knowledge construction and peer communication.

For students in K-12 education, this sudden transition is problematic as they often lack prior online learning experience (Barbour & Reeves, 2009). Barbour and LaBonte (2017) estimated that even in countries where online learning is growing rapidly, like the USA and Canada, less than 10 percent of the K-12 student population had prior experience with this format. Maladaptation to online learning could expose inexperienced students to various vulnerabilities, including decrements in academic performance (Miron & Gulosino, 2016; Molnar et al., 2017; Molnar et al., 2019), feeling of isolation (Hrastinski, 2008; Song, Singleton, Hill, & Koh, 2004), and lack of learning motivation (Muilenburg & Berge, 2005; Song et al., 2004). Unfortunately, with confirmed cases continuing to rise each day, and new outbreaks occur on a global scale, full-time online learning for most students could last longer than anticipated (World Health Organization, 2020). Even after the pandemic, the current mass adoption of online learning could have lasting impacts on the global education system, and potentially accelerate and expand the rapid growth of virtual schools on a global scale (Molnar et al., 2019). Thus, understanding students' learning conditions and their experiences of online learning during the COVID pandemic become imperative.

Emerging evidence on students' online learning experience during the COVID-19 pandemic has identified several major concerns, including issues with internet connection (Basuony, EmadEldeen, Farghaly, El-Bassiouny, & Mohamed, 2020; Agung, Surtikanti, Quinones, et al., 2020), problems with IT equipment (Bączek, Zagańczyk-Bączek, Szpringer, Jaroszyński, & Wożakowska-Kapłon, 2021; Niemi, Kousa, et al., 2020), limited collaborative learning opportunities (Bączek et al., 2021; Yates, Starkey, Egerton, & Flueggen, 2020), reduced learning motivation (Basuony et al., 2020; Yates et al., 2020; Niemi et al., 2020), and increased learning burdens (Niemi et al., 2020). Although these findings provided valuable insights about the issues students experienced during online learning, information about

their learning conditions and future expectations were less mentioned. Such information could assist educational authorises and institutions to better comprehend students' difficulties and potentially improve their online learning experience. Additionally, most of these recent studies were limited to higher education, except for Yates et al. (2020) and Niemi et al.'s (2020) studies on senior high school students. Empirical research targeting the full spectrum of K-12 students remain scarce. Therefore, to address these gaps, the current paper reports the findings of a large-scale study that sought to explore K-12 students' online learning experience during the COVID-19 pandemic in a provincial sample of over one million Chinese students. The findings of this study provide policy recommendations to educational institutions and authorities regarding the delivery of K-12 online education.

2. Literature Review

2.1. Learning conditions and technologies

Having stable access to the internet is critical to students' learning experience during online learning. Berge (2005) expressed the concern of the divide in digital-readiness, and the pedagogical approach between different countries could influence students' online learning experience. Digital-readiness is the availability and adoption of information technologies and infrastructures in a country. Western countries like America (3rd) scored significantly higher in digital-readiness compared to Asian countries like China (54th; Cisco, 2019). Students from low digital-readiness countries could experience additional technology-related problems. Supporting evidence is emerging in recent studies conducted during the COVID-19 pandemic. In Egypt's capital city, Basuony et al. (2020) found that only around 13.9% of the students experienced issues with their internet connection. Whereas more than two-thirds of the students in rural Indonesia reported issues of unstable internet, insufficient internet data, and incompatible learning device (Agung et al., 2020).

Another influential factor for K-12 students to adequately adapt to online learning is the accessibility of appropriate technological devices, especially having access to a desktop or a laptop (Barbour, Huerta, & Miron, 2018). However, it is unlikely for most of the students to satisfy this requirement. Even in higher education, around 76% of students reported having incompatible devices for online learning and only 15% of students used laptop for online learning, whereas around 85% of them used smartphone (Agung et al., 2020). It is very likely that K-12 students also suffer from this device-availability issue as they depend on their parents to provide access to relevant learning devices.

Technical issues surrounding technological devices could also influence students' experience in online learning. (Barbour & Reeves, 2009) argues that students need to have a high level of digital literacy to find and use relevant information and communicate with others through technological devices. Students lacking this ability could experience difficulties in online learning. Bączek et al. (2021) found that around 54% of the medical students experienced technical problems with IT equipment and this issue was more prevalent in students with lower years of tertiary education. Likewise, Niemi et al. (2020) also find that students in a Finish high school experienced increased amounts of technical problems during the examination period, which involved additional technical applications. These findings are concerning as young children and adolescent in primary and lower secondary school could be more vulnerable to these technical problems as they are less experienced with the technologies in online learning (Barbour & LaBonte, 2017). Therefore, it is essential to investigate the learning conditions and the related difficulties experienced by students in K-12 education as the extend of effects on them remain underexplored.

2.2. Learning experience and interactions

Apart from the aforementioned issues, the extent of interaction and collaborative learning opportunities available in online learning could also influence students' experience. The literature on online learning has long emphasized the role of effective interaction for the success of student learning. According to Muirhead and Juwah (2004), interaction is an event that can take the shape of any type of communication between two or subjects and objects. Specifically, the literature acknowledges the three typical forms of interactions(Moore, 1989): i) student-content, ii) student-student, and iii) student-teacher. Anderson (2003) posits, in the well-known interaction equivalency theorem, learning experiences will not deteriorate if only one of the three interaction is of high quality, and the other two can be reduced or even eliminated. Quality interaction can be accomplished by across two dimensions: i) structure – pedagogical means that guide students interaction with contents or other students and i) dialogue – communication that happens between students and teachers and among students. To be able to scale online learning and prevent the growth of teaching costs, the emphasize is typically on structure (i.e., pedagogy) that can promote effective student-content and student-student interaction. The role of technology and media is typically recognized as a way to amplify the effect of pedagogy (Lou,

Bernard, & Abrami, 2006). Novel technological innovations – e.g., learning analytics-based personalized feedback at scale (Pardo, Jovanovic, Dawson, Gašević, & Mirriahi, 2019) – can also empower teachers to promote their interaction with students.

Online education can lead to a sense of isolation, which can be detrimental to student success (McInnerney & Roberts, 2004). Therefore, integration of social interaction into pedagogy for online learning is essential, especially at the times when students do not actually know each other or have communication and collaboration skills underdeveloped (Garrison, Cleveland-Innes, & Fung, 2010; Gašević, Adesope, Joksimović, & Kovanović, 2015). Unfortunately, existing evidence suggested that online learning delivery during the COVID-19 pandemic often lacks interactivity and collaborative experiences (Bączek et al., 2021; Yates et al., 2020). Bączek et al. (2021) found that around half of the medical students reported reduced interaction with teachers, and only 4% of students think online learning classes are interactive. Likewise, Yates et al. (2020)'s study in high school students also revealed that over half of the students preferred in-class collaboration over online collaboration as they value the immediate support and the proximity to teachers and peers from in-class interaction.

2.3. Learning expectations and age differentiation

Although these studies have provided valuable insights and stressed the need for more interactivity in online learning, K-12 students in different school years could exhibit different expectations for the desired activities in online learning. Piaget's Cognitive Developmental Theory illustrated children's difficulties in understanding abstract and hypothetical concepts (Thomas, 2000). Primary school students will encounter many abstract concepts in their STEM education (Uttal & Cohen, 2012). In face-to-face learning, teachers provide constant guidance on students' learning progress and can help them to understand difficult concepts. Unfortunately, the level of guidance significantly drops in online learning, and, in most cases, children have to face learning obstacles by themselves (Barbour, 2013). Additionally, lower primary school students may lack the metacognitive skills to use various online learning functions, maintain engagement in synchronous online learning, develop and execute self-regulated learning plans, and engage in meaningful peer interactions during online learning (Huffaker & Calvert, 2003; Barbour, 2013; C.-H. Wang, Shannon, & Ross, 2013; Broadbent & Poon, 2015). Thus, understanding these younger students' expectations is imperative as delivering online learning to them in the same way as a virtual high school could hinder their learning experiences.

For students with more matured metacognition, their expectations of online learning could be substantially different from younger students. Niemi et al.'s study (2020) with students in a Finish high school have found that students often reported heavy workload and fatigue during online learning. These issues could cause anxiety and reduce students' learning motivation, which would have negative consequences on their emotional well-being and academic performance (Yates et al., 2020; Niemi et al., 2020), especially for senior students who are under the pressure of examinations. Consequently, their expectations of online learning could be orientated toward having additional learning support functions and materials. Likewise, they could also prefer having more opportunities for peer interactions as these interactions are beneficial to their emotional well-being and learning performance (Montague & Rinaldi, 2001; Gašević, Zouaq, & Janzen, 2013). Therefore, it is imperative to investigate the differences between online learning expectations in students of different school years to suit their needs better.

3. Research Questions

By building upon the aforementioned relevant works, this study aimed to contribute to the online learning literature with a comprehensive understanding of the online learning experience that K-12 students had during the COVID-19 pandemic period in China. Additionally, this study also aimed to provide a thorough discussion of what potential actions can be undertaken to improve online learning delivery. Formally, this study was guided by three **R**esearch **Q**uestions:

RQ1 What learning conditions were experienced by students across 12 years of education during their online learning process in the pandemic period?

RQ2 What benefits and obstacles were perceived by students across 12 years of education when performing online learning?

RQ3 What expectations do students, across 12 years of education, have for future online learning practices?

Table 1
The number of students of different school years involved in our study.

School Year	# Students	% Students	School Year	# Students	% Students
1	87,817	8.37%	7	107,747	10.28%
2	89,998	8.58%	8	100,972	9.63%
3	95,166	9.08%	9	90,039	8.59%
4	102,109	9.74%	10	59,028	5.63%
5	106,397	10.15%	11	54,946	5.24%
6	104,259	9.94%	12	50,097	4.78%
				Total:	1,048,575

To answer these RQs, we designed a set of different questions and embedded them in a survey sent out by the Department of Education in the [Anonymous] Province in China to all of the K-12 students residing in the province to enable a better understanding of students' online learning experience during the pandemic period.

4. Material and Methods

In this section, we first introduce the participants involved in our study, followed by the description of the survey design. Then, we detail the procedure we adopted to run the survey. Lastly, we describe the analysis we performed on the collected data.

4.1. Participants

The total number of K-12 students in the [Anonymous] Province of China is around 15 million. In China, students of Year 1-6, Year 7-9, and Year 10-12 are referred to as students of primary school, middle school, and high school, respectively. Typically, students in China start their study in primary school at the age of around six. At the end of their high-school study, students have to take the National College Entrance Examination (also known as Gaokao) to apply for tertiary education. The survey was administrated across the whole [Anonymous] Province, i.e., the survey was exposed to all of the 15 million K-12 students, though it was not mandatory for those students to accomplish the survey. A total of 1,170,769 students completed the survey, which accounts for a response rate of 7.80%. After removing responses with missing values and responses submitted from the same IP address (thus can be regarded as duplicates), we had 1,048,575 valid responses, which accounts to about 7% of the total K-12 students in the [Anonymous] Province. The number of students in different school years is given in Table 1. Overall, students were evenly distributed across different school years, except for a smaller sample in students of Year 10-12.

4.2. Survey design

The survey was designed collaboratively by multiple relevant parties. Firstly, three educational researchers working in colleges and universities and three educational practitioners working in the Department of Education in [Anonymous] Province were recruited to co-design the survey. Then, the initial draft of the survey was sent to 30 teachers from different primary and secondary schools, whose feedback and suggestions were taken into account to improve the survey. The final survey consisted of a total of 20 questions, which, broadly, can be classified into four categories, as shown in Table 2 and elaborated below.

- **Demographic.** In order to gain a better understanding of the experiences and needs of different students for online learning, the final survey contained two questions collecting students' demographic information, i.e., Q1 asking the location and type of the school where a student was undertaking studies and Q2 asking the school year that the student was in.

- **Behaviors.** There are nine questions surveying students about their behaviors or behavior-related information, including Q3, Q4, Q5, Q6, Q8, Q10, Q11, Q12, and Q14. These questions together examined a variety of students' online learning behaviors, e.g., the usage of different learning media (Q3), the longest duration of a

Table 2
The questions we designed to survey students about their online learning experiences.

Dimensions	Question Text	Question Types
Demographic	**Q1.** What is the location and category of your school:	Single-response MCQ
	Q2. Which school year are you in?	Single-response MCQ
Behaviors	**Q3.** What equipments and materials did you use for online learning during the COVID-19 pandemic period?	Multiple-response MCQ
	Q4. Other than the lecture function, which features of the online education platform have you used?	Multiple-response MCQ
	Q5. What is the longest class time for your online courses?	Single-response MCQ
	Q6. How long do you study online every day?	Slider questons
	Q8. Did you need family companionship when studying online?	Single-response MCQ
	Q10. What content does your online course include?	Multiple-response MCQ
	Q11. What approaches did you use to tackle the unlearnt concepts you had when performing online learning?	Multiple-response MCQ
	Q12. How often do you interact with your classroom in online learning?	Single-response MCQ
	Q14. Regarding the following online learning behaviours, please select the answer that fits your situationin the form below.	Yes/No Questions
Experiences	**Q7.** Which of the following learning statuses is appropriate for your situation?	Multiple-response MCQ
	Q9. What is the online classroom/learning format that you enjoyed?	Single-response MCQ
	Q13. What obstacles did you encounter when studying online?	Multiple-response MCQ
	Q15. What skills do you think are developed from online education?	Multiple-response MCQ
	Q16. How satisfied are you with the following aspects of online learning?	Four-point bipolar scale
	Q17. Compared to classroom-based learning, what are the advantages of online learning?	Multiple-response MCQ
	Q18. What do you think are the deficiencies of online learning compared to physical classrooms?	Multiple-response MCQ
Expectations	**Q19.** What online activities or experiences do you expect to have that will enhance your online learning?	Multiple-response MCQ
	Q20. After the COVID-19 pandemic, which type of learning would you prefer?	Single-response MCQ

class they had (Q5), the extent to which they are accompanied by family (Q8), the approaches they adopted to tackle unlearnt concepts (Q11), and such. These questions were measured using nominal scales.

- **Experiences.** A total of 6 questions (i.e., Q7, Q13, Q15, Q16, Q17, and Q18) were adopted to pry into students' general experiences when performing online learning, including the main obstacles stopping them from engaging with online learning (Q13), the skills that they have developed from performing online learning (Q15), the main benefits brought by online learning (Q17), and such. Nominal scales were used in these questions.

- **Expectations.** Q19 and Q20 were the only two questions adopted to elicit students' Expectations for future

online learning practices, which ask about their expectations for the activities in online learning (Q19) and their overall preference for the type of learning (e.g., classroom-based learning vs. online learning) after the COVID-19 pandemic. Students answered these two questions by choosing items from nominal scales.

4.3. Procedure

All K-12 students in the [Anonymous] Province were made to have full-time online learning from March 1, 2020 after the outbreak of COVID-19 in January in China. A province-level online learning platform was provided to all schools by the government. In addition to the learning platform, these schools can also use additional third-party platforms to facilitate the teaching activities, e.g., WeChat and Dingding, which provide services similar to WhatsApp and Zoom. The main change for most teachers was that they had to shift the classroom-based lectures to online lectures with the aid of web-conferencing tools. Similarly, these teachers also needed to perform homework marking and have consultation sessions in an online manner.

The Department of Education in the [Anonymous] Province of China distributed the survey to all K-12 schools in the province on March 21, 2020, and collected responses on March 26, 2020. Students could access and answer the survey anonymously by either scan the Quick Response code along with the survey or click the survey address link on their mobile device. The survey was administrated in a completely voluntary manner and no incentives were given to the participants. Ethical approval was granted by the Department of Education in the [Anonymous] Province. Parental approval was not required since the survey was entirely anonymous and facilitated by the regulating authority, which satisfies China's ethical process.

4.4. Analysis

The original survey was in Chinese, which was later translated by two bilingual researchers and verified by an external translator who is certified by the Australian National Accreditation Authority of Translators and Interpreters. Appendix A and B detail the original and translated survey questionnaires, respectively. To answer the RQs proposed in Section 3, we used cross-tabulation based approaches to analyze the collected data. To scrutinize whether the differences displayed by students of different school years were statistically significant, we performed Chi-square tests and calculated the Cramer's V to assess the strengths of the association after chi-square had determined significance.

Recall that we were mainly interested in investigating the online learning experiences that students of different school years had during the COVID-19 pandemic period. More specifically, we focused on depicting students' learning conditions (RQ1), the benefits and obstacles perceived by them (RQ2), and their expectations for future online learning practices (RQ3). Given the limited space we have here and the fact that not every question is relevant to answer those RQs, we selected and analyzed the most relevant ones in Section 5, i.e., Q3, Q8, and Q11 for RQ1, Q13 and Q19 for RQ2, Q19 and Q20 for RQ3.

5. Results

As described in Section 4.2, with the survey, we mainly aimed to measure students' online learning experience during the COVID-19 pandemic, including (i) the learning conditions, (ii) the perceived benefits and obstacles of online learning, and (iii) the expectations for future practices of online learning, whose results are detailed below. It is worth noting that our survey was administrated to cover the students of all school years in China: elementary school (Year 1-6), middle school (Year 7-9), and high school (Year 10-12). Children in elementary school can further be segmented into junior (Year 1-3) or senior (Year 4-6) students because senior elementary students in China are facing more workloads compared to junior students due to the provincial Middle School Entry Examination at the end of Year 6. Therefore, we segmented students into four categories based on their school years, i.e., Year 1–3, Year 4–6, Year 7–9, and Year 10–12, with which we expected to provide a clear understanding of the different experiences and needs that different students had for online learning. The complete results of students of every school year are given in the Appendix C.

5.1. Learning Conditions – RQ1

The survey items relevant to students' learning conditions include Q3, Q8, and Q11, which asked about the learning media used by students, the family companion students had during the learning process, and the approaches adopted by students to tackle unlearnt concepts, respectively.

Learning media. The Chi-square test showed significant association between school years and students' reported usage of learning media, $\chi^2(55, N = 1853952) = 46675.38$, $p < .001$. The Cramer's V is 0.07 ($df^* = 5$), which

Table 3
Results on Q3, which surveyed the learning media used by students in online learning. All results are in percentages. The results in the column `All` were calculated by taking students of all school years into account. The top 3 results of each school year (i.e., each column) are marked in bold; and the results that are below the corresponding `All` value in the same row are marked with grey background.

School Year	1-3	4-6	7-9	10-12	All
TV	**24.64**	**22.14**	14.72	9.78	18.64
Computer	**20.70**	**22.81**	27.83	33.45	25.43
Tablet	19.87	18.08	13.92	13.36	16.78
Smartphone	**83.25**	**86.26**	89.34	92.63	87.39
Audio	4.10	4.78	5.13	5.81	4.94
Paper-based materials	17.32	19.94	**25.53**	**36.32**	23.63

Table 4
Results on Q8, which surveyed to what extent students were accompanied by their families during the online learning process. All results are in percentages. The results in the column `All` were calculated by taking students of all school years into account. The results that are below the corresponding `All` value in the same row are marked with grey background.

School Year	1-3	4-6	7-9	10-12	All
Not at all	16.56	46.58	72.91	86.66	52.59
Sometime	65.05	48.28	24.91	11.73	40.30
Always	18.38	5.14	2.18	1.61	7.10

indicates a small-to-medium effect according to Cohen's (1988) guidelines. Based on Table 3, we observed that an average of up to 87.39% students used smartphones to perform online learning, while only 25.43% students used computer, which suggests that smartphones, with widespread availability in China (2020), have been adopted by students for online learning. As for the prevalence of the two media, we noticed that both smartphones ($\chi^2(3, N = 1048575) = 9395.05$, $p < .001$, Cramer's $V = 0.10$ ($df^* = 1$)) and computers ($\chi^2(3, N = 1048575) = 11025.58$, $p < .001$, Cramer's $V = 0.10$ ($df^* = 1$)) were more adopted by high-school-year students (Year 7-12) than early-school-year ones (Year 1-6), both with a small effect size. Besides, apparent discrepancies can be observed between the usages of TV and paper-based materials across different school years, i.e., early-school-year students reported more TV usage ($\chi^2(3, N = 1048575) = 19505.08$, $p < .001$), with a small-to-medium effect size, Cramer's $V = 0.14$ ($df^* = 1$). In contrast, high-school-year students (especially Year 10-12) reported more usage of paper-based materials ($\chi^2(3, N = 1048575) = 23401.64$, $p < .001$), with a small-to-medium effect size, Cramer's $V = 0.15$ ($df^* = 1$).

Family companionship. The association between school years and students' need of family companionship is statistically significant, $\chi^2(22, N = 1048575) = 323442.91, p < .001$. The Cramer's V (0.39, $df^* = 2$) indicates a strong association between these two variables (Cohen, 1988). As shown in Table 4, early-school-year students, especially those from Year 1-3 (18.38% Always and 65.05% Sometime), required much more family companionship to support their online learning compared to high-school-year students (5.14% – 1.61% Always and 48.28% – 11.73% Sometime).

Learning approaches. School years is also significantly associated with the different learning approaches students used to tackle difficult concepts during online learning, $\chi^2(55, N = 2383751) = 58030.74, p < .001$. The strength of this association is weak to moderate as shown by the Cramer's V (0.07, $df^* = 5$; Cohen, 1988). When encountering problems related to difficult concepts, students typically chose to "*solve independently by searching online*" or "*rewatch recorded lectures*" instead of consulting to their teachers or peers (Table 5). This is probably because, compared to classroom-based education, it is relatively less convenient and more challenging for students to seek help from others when performing online learning. Besides, compared to high-school-year students, early-school-year students (Year 1–6), reported much less use of "*solve independently by searching online*" ($\chi^2(3, N = 1048575) = 48100.15$, $p < .001$), with a small-to-medium effect size, Cramer's $V = 0.21$ ($df^* = 1$). Also, it is worth noting that, among those approaches of seeking help from others, significantly more high-school-year students preferred "*communicating with*

Table 5
Results on Q11, which surveyed the approaches used by students to master the unlearnt concepts in online learning. All results are in percentages. The results in the column `All` were calculated by taking students of all school years into account. The top 3 results of each school year (i.e., each column) are marked in bold; and the results that are below the corresponding `All` value in the same row are marked with grey background.

School Year	1-3	4-6	7-9	10-12	All
Solve independently by searching online	**34.12**	**44.78**	**54.62**	**65.68**	48.20
Re-watch recorded lectures	**71.40**	**72.38**	**70.73**	**68.03**	71.02
Attend Q&A sessions organized by teachers	23.16	27.35	30.49	29.95	27.74
Ask teachers by using social platforms	**31.60**	**33.80**	40.53	39.54	**36.07**
Communicate with other students	15.35	29.89	**48.14**	**45.68**	33.98
Leave it for later	12.59	8.79	9.23	12.95	10.33

Table 6
Results on Q17, which surveyed the benefits of online learning perceived by students. All results are in percentages. The results in the column `All` were calculated by taking students of all school years into account. The top 3 results of each school year (i.e., each column) are marked in bold; and the results that are below the corresponding `All` value in the same row are marked with grey background.

School Year	1-3	4-6	7-9	10-12	All
Access to courses delivered by famous teachers	**47.66**	**50.63**	42.81	39.10	**45.86**
More convenient to review course content	**68.88**	**73.72**	**77.80**	**78.90**	74.48
Achieve better learning performance	15.18	23.78	19.80	15.02	19.11
Less learning efforts are required	13.25	19.92	18.10	15.51	17.04
Helpful to develop self-regulation and autonomy	31.46	41.32	**46.88**	**40.35**	40.29
Can learn anytime and anywhere	**55.06**	**53.16**	**52.71**	**57.02**	54.12

other students" than early-school-year students ($\chi^2(3, N = 1048575) = 81723.37$, $p < .001$), with a medium effect size, Cramer's $V = 0.28$ ($df^* = 1$).

5.2. Perceived Benefits and Obstacles – RQ2

Perceived benefits. The association between school years and perceived benefits in online learning is statistically significant, $\chi^2(66, N = 2716127) = 29534.23$, $p < .001$, and the Cramer's V (0.04, $df^* = 6$) indicates a small effect (Cohen, 1988). Unsurprisingly, benefits brought by the convenience of online learning are widely recognized by students across all school years (Table 6), i.e., up to 75% students reported that it is "*more convenient to review course content*" and 54% said that they "*can learn anytime and anywhere*". Besides, we noticed that about 50% early-school-year students appreciated the "*access to courses delivered by famous teachers*" and 40% 47% high-school-year students indicated that online learning is "*helpful to develop self-regulation and autonomy*".

Perceived obstacles. The Chi-square test shows a significant association between school years and students' perceived obstacles in online learning, $\chi^2(77, N = 2699003) = 31987.56$, $p < .001$. This association is relatively weak as shown by the Cramer's V (0.04, $df^* = 7$; Cohen, 1988). As shown in Table 7, the biggest obstacles encountered by up to 73% of students were the "*eyestrain caused by long staring at screens*". Disengagement caused by nearby disturbance was reported by around 40% of students, especially those of Year 1-3 and 10-12. Technological-wise, about 50% of students experienced poor Internet connection during their learning process, and around 20% students reported the "*confusion in setting up the platforms*" across of school years.

5.3. Expectations for Future Practices of Online Learning – RQ3

Online learning activities. The association between school years and students' expected online learning activities is significant, $\chi^2(66, N = 2416093) = 38784.81$, $p < .001$. The Cramer's V is 0.05 ($df^* = 6$) which suggests a small

Table 7
Results on Q13, which surveyed the obstacles encountered by students in online learning. All results are in percentages. The results in the column All were calculated by taking students of all school years into account. The top 3 results of each school year (i.e., each column) are marked in bold; and the results that are below the corresponding All value in the same row are marked with grey background.

School Year	1-3	4-6	7-9	10-12	All
Poor Internet connection	**45.29**	**50.96**	**51.46**	**49.61**	49.48
Poor experience with online learning platforms	23.93	22.66	22.41	25.01	23.27
Insufficient communication with teachers	30.62	27.16	23.44	23.03	26.37
Excessive homework assignments	5.90	7.77	11.75	16.73	9.80
Poor course design/delivery	14.88	14.75	13.80	15.35	14.61
Eyestrain caused by long staring at screens	**71.35**	**70.75**	**74.07**	**79.20**	73.15
Confusion in setting up the platforms	20.17	22.53	19.55	21.11	20.86
Disengagement caused by nearby disturbance	**47.99**	**35.14**	**34.82**	**45.16**	39.86

Table 8
Results on Q19, which surveyed the activities expected by students for future online learning. All results are in percentages. The results in the column All were calculated by taking students of all school years into account. The top 3 results of each school year (i.e., each column) are marked in bold; and the results that are below the corresponding All value in the same row are marked with grey background.

School Year	1-3	4-6	7-9	10-12	All
Real-time interaction with teachers	**60.08**	**57.68**	**50.47**	46.62	54.53
Online group discussion and collaboration	26.63	**40.01**	**44.14**	**37.32**	37.63
Increase the content and length of special education	28.11	29.93	30.00	28.23	29.18
Regular online practice examinations	**37.36**	**35.11**	31.20	22.68	32.65
Intelligent recommendation system for learning resource	25.19	31.11	**36.24**	**41.99**	32.84
Intelligent monitoring and feedback system for learning	**32.72**	32.23	32.86	33.22	32.71

Table 9
Results on Q20, which surveyed the formats of teaching and learning preferred by students in the post COVID-19 era. All results are in percentages. The results in the column All were calculated by taking students of all school years into account. The results that are below the corresponding All value in the same row are marked with grey background.

School Year	1-3	4-6	7-9	10-12	All
Classroom-based learning	52.50	54.89	48.15	35.46	49.40
Classroom-based learning with online resources as supplement	35.37	29.95	33.07	41.12	33.84
Blended learning	8.51	9.31	13.27	19.17	11.78
Online learning	3.63	5.84	5.51	4.25	4.98

effect (Cohen, 1988). As shown in Table 8, the most expected activity for future online learning is "*real-time interaction with teachers*" (55%), followed by "*online group discussion and collaboration*" (38%). We also observed that more early-school-year students expect reflective activities, such as "*regular online practice examinations*" ($\chi^2(3, N = 1048575) = 11644.98$, $p < .001$), with a small effect size, Cramer's $V = 0.11$ ($df^* = 1$). In contrast, more high-school-year students expect "*intelligent recommendation system for learning resource*" ($\chi^2(3, N = 1048575) = 15327.00$, $p < .001$), with a small effect size, Cramer's $V = 0.12$ ($df^* = 1$).

Preference for learning types. School years is also significantly associated with students' reported preference for

learning types, $\chi^2(33, N = 1048575) = 30252.71, p < .001$, and the Cramer's V is 0.10 ($df^* = 3$) which indicates a small-to-medium effect (Cohen, 1988). About 50% of students still preferred having "*classroom-based learning*" (Table 9), and early-school-year students tended to display a higher preference for classroom-based learning than high-school-year students ($\chi^2(3, N = 1048575) = 10590.00, p < .001$), with a small effect size, Cramer's $V = 0.10$ ($df^* = 1$). Though, it is worthy of attention that at least about half of the students realized the benefits brought by online learning, i.e., 34% students chose "*classroom-based learning with online resources as supplement*", 12% for "*blended learning*", and 5% for pure "*online learning*".

6. Discussion

6.1. Learning Conditions – RQ1

In regards to students' learning conditions, substantial differences were observed in learning media, family dependency, and learning approaches adopted in online learning between students in different school years. The finding of more computer and smartphone usage in high-school-year than early-school-year students can probably be explained by that, with the growing abilities in utilizing these media as well as the educational systems and tools which run on these media, high-school-year students tend to make better use of these media for online learning practices. Whereas, the differences in paper-based materials may imply that high-school-year students in China have to accomplish a substantial amount of exercise, assignments, and exam papers to prepare for the National College Entrance Examination (NCEE), whose delivery was not entirely digitized due to the sudden transition to online learning. Meanwhile, high-school-year students may also have preferred using paper-based materials for exam practice, as eventually, they would take their NCEE in the paper format. Therefore, these substantial differences in students' usage of learning media should be addressed by customising the delivery method of online learning for different school years.

Other than these between-age differences in learning media, the prevalence of smartphone in online learning resonates with Agung et al.'s (Agung et al., 2020) finding on the issues surrounding the availability of compatible learning device. The prevalence of smartphone in K-12 students is potentially problematic as the majority of the online learning platform and content is designed for computer-based learning (Berge, 2005; Molnar et al., 2019). Whereas learning with smartphones has its own unique challenges. For example, Gikas and Grant (2013) discovered that students who learn with smartphone experienced frustration with the small screen-size, especially when trying to type with the tiny keypad. Another challenge relates to the distraction of various social media applications. Although similar distractions exist in computer and web-based social media, the level of popularity, especially in the young generation, are much higher in mobile-based social media (Montag, Becker, & Gan, 2018). In particular, the message notification function in smartphones could disengage students from learning activities and allure them to social media applications (Gikas & Grant, 2013). Given these challenges of learning with smartphones, more research efforts should be devoted to analyzing students' learning behaviour in the setting of mobile learning to accommodate their needs better.

The greater need for family companionship in early-school-year students echoes with the speculations made in (Rice, 2006). That is, the underdeveloped metacognition of early-school-year students may attribute to their need for family companionship since the high-level metacognitive skills required for online learning (e.g., self-regulation and self-direction) are less accessible for these students, independently. Thus, they need the presence of family members to regulate and guide their learning. On the other hand, metacognition is more matured in high-school-year students (Crone & Konijn, 2018). These older students would also like to be seen as more independent and less reliant on their families, thus reported less need for family companionship during online learning. This contrast between low- and high-school-year students stress the importance of providing sufficient guidance when delivering online learning to younger children.

The differences in learning approaches, once again, illustrated that early-school-year students have different needs compared to high-school-year students. In particular, the low usage of the independent learning methods in early-school year students may reflect their inability to engage in independent learning. Beside, the differences in help seeking behaviours demonstrated the distinctive needs for communication and interaction between different students, i.e., early-school-year students have a strong reliance on teachers and high-school-year students, who are equipped with stronger communication ability, are more inclined to interact with their peers. This finding implies that the design of online learning platforms should take students' different needs into account. Thus, customization is urgently needed for the delivery of online learning to different school years.

6.2. Perceived Benefits and Obstacles – RQ2

In terms of the perceived benefits and challenges of online learning, our results resonate with several previous findings. In particular, the benefits of convenience are in line with the flexibility advantages of online learning, which were mentioned in prior works (Appana, 2008; Barbour, 2013; Harvey, Greer, Basham, & Hu, 2014; Basuony et al., 2020; Bączek et al., 2021). Early-school-year students' higher appreciation in having "*access to courses delivered by famous teachers*" and lower appreciation in the independent learning skills developed through online learning are also in line with previous literature (Harvey et al., 2014; Oliver, Osborne, & Brady, 2009; Barbour, 2013). Again, these similar findings may indicate the strong reliance that early-school-year students place on teachers, while high-school-year students are more capable of adapting to online learning by developing independent learning skills.

Technology-wise, students' experience of poor internet connection and confusion in setting up online learning platforms are particularly concerning. The problem of poor internet connection corroborated the findings reported in prior studies (Barbour, 2013; Berge, 2005; Rice, 2006; Basuony et al., 2020; Agung et al., 2020), i.e., the access issue surrounded the digital divide as one of the main challenges of online learning. In the era of 4G and 5G networks, educational authorities and institutions who deliver online education could fall into the misconception of most students have a stable internet connection at home. The internet issue we observed is particularly vital to students' online learning experience as most students prefer real-time communications (Table 8), which rely heavily on stable internet connection. Likewise, the finding of students' confusion in technology is also consistent with prior studies (Song et al., 2004; Muilenburg & Berge, 2005; Bączek et al., 2021; Niemi et al., 2020). Students who were unsuccessfully in setting up the online learning platforms could potentially experience declines in confidence and enthusiasm for online learning, which would cause a subsequent unpleasant learning experience. Therefore, both the readiness of internet infrastructure and student technical skills remain as the significant challenges for the mass-adoption of online learning.

On the other hand, the finding of students' experience of eyestrain from extended screen time provided empirical evidence to support Spitzer's (2001) speculation about the potential ergonomic impact of online learning. This negative effect is potentially related to the prevalence of smartphone device and the limited screen size of these devices. Such a finding, undoubtedly, not only demonstrates the potential ergonomic issues that would be caused by smartphone-based online learning but also resonates with the aforementioned necessity of different platforms and content designs for different students.

A less-mentioned problem in previous studies on online learning experiences is the disengagement caused by nearby disturbance, especially in Year 1-3 and 10-12. It is likely that early-school-year students suffered from this problem because of their underdeveloped metacognitive skills to concentrate on online learning without teachers' guidance. As for high-school-year students, the reasons behind their disengagement require further investigation in the future. Especially it would be worthwhile to scrutinize whether this type of disengagement is caused by the substantial amount of coursework they have to undertake and the subsequent a higher level of pressure and a lower level of concentration while learning.

6.3. Expectations for Future Practices of Online Learning – RQ3

Across age-level differences are also apparent in terms of students' expectations of online learning. Although, our results demonstrated students' needs of gaining social interaction with others during online learning, which is consistent with previous findings (Harvey et al., 2014; Liu & Cavanaugh, 2012; Kuo, Walker, Belland, Schroder, & Kuo, 2014; Bączek et al., 2021; Yates et al., 2020). This need manifested differently across school years, with early-school-year students preferring more teacher interactions and learning regulation support. Once again, this finding may imply that early-school-year students are inadequate in engaging with online learning without proper guidance from their teachers. Whereas, high-school-year students prefer more peer interactions and recommendation to learning resources. This expectation can probably be explained by the large amount of coursework exposed to them. Thus, high-school-year students need further guidance to help them better direct their learning efforts. These differences in students' expectations for future practices could guide the customisation of online learning delivery.

For future learning, classroom-based learning remains the preferred learning format for the majority of the students across school years. This finding is understandable, especially for early-school-year students, as they have demonstrated the desire for real-time interaction and external guidance consistently throughout our survey, which is more available in classroom-based than online learning. However, students, especially senior students, also recognised the benefits of online learning and would like to have online learning to supplement their classroom-based learning or in the format of blended learning. This greater acceptance in high-school-year students is in line with the previous findings we had, i.e., with a growing capability in learning independently, high-school-year students are more likely to make better use

of online learning than early-school-year students.

6.4. Implications

As shown in our results, improving the delivery of online learning not only requires the efforts of policymakers but also depend on the actions of teachers and parents. The following sub-sections will provide recommendations for relevant stakeholders and discuss their essential roles in supporting online education.

Technical support. The majority of the students has experienced technical problems during online learning, including internet lagging and confusion in setting up the learning platforms. These problems with technology could impair students' learning experience (Kauffman, 2015; Muilenburg & Berge, 2005). Educational authorities and schools should always provide a thorough guide and assistance for students who are experiencing technical problems with online learning platforms or other related tools. Early screening and detection could also assist schools and teachers to direct their efforts more effectively in helping students with low technology skills (Wilkinson, Roberts, & While, 2010). A potential identification method involves distributing age-specific surveys that assess students' Information and Communication Technology (ICT) skills at the beginning of online learning. For example, there are empirical validated ICT surveys available for both primary (Aesaert, Van Nijlen, Vanderlinde, & van Braak, 2014) and high school (Claro et al., 2012) students.

For students who had problems with internet lagging, the delivery of online learning should provide options that require fewer data and bandwidth. Lecture recording is the existing option but fails to address students' need for real-time interaction (Clark, Strudler, & Grove, 2015; Malik & Fatima, 2017). A potential alternative involves providing students with the option to learn with digital or physical textbooks and audio-conferencing, instead of screen sharing and video-conferencing. This approach significantly reduces the amount of data usage and lowers the requirement of bandwidth for students to engage in smooth online interactions (Cisco, 2018). It also requires little additional efforts from teachers as official textbooks are often available for each school year, and thus, they only need to guide students through the materials during audio-conferencing. Educational authority can further support this approach by making digital textbooks available for teachers and students, especially those in financial hardship. However, the lack of visual and instructor presence could potentially reduce students' attention, recall of information, and satisfaction in online learning (J. Wang & Antonenko, 2017). Therefore, further research is required to understand whether the combination of digital or physical textbooks and audio-conferencing is appropriate for students with internet problems. Alternatively, suppose the local technological infrastructure is well developed. In that case, governments and schools can also collaborate with internet providers to issue data and bandwidth vouchers for students who are experiencing internet problems due to financial hardship.

For future adoption of online learning, policymakers should consider the readiness of the local internet infrastructure. This recommendation is particularly important for developing countries, like Bangladesh, where the majority of the students reported the lack of internet infrastructure (Ramij & Sultana, 2020). In such environments, online education may become infeasible, and alternative delivery method could be more appropriate, for example, the Telesecundaria program provides TV education for rural areas of Mexico (Calderoni, 1998).

Other than technical problems, choosing a suitable online learning platform is also vital for providing students with a better learning experience. Governments and schools should choose an online learning platform that is customised for smartphone-based learning, as the majority of students could be using smartphones for online learning. This recommendation is highly relevant for situations where students are forced or involuntarily engaged in online learning, like during the COVID-19 pandemic, as they might not have access to a personal computer (Molnar et al., 2019).

Customisation of delivery methods. Customising the delivery of online learning for students in different school years is the theme that appeared consistently across our findings. This customisation process is vital for making online learning an opportunity for students to develop independent learning skills, which could help prepare them for tertiary education and lifelong learning. However, the pedagogical design of K-12 online learning programs should be differentiated from adult-orientated programs as these programs are designed for independent learners, which is rarely the case for students in K-12 education (Barbour & Reeves, 2009).

For early-school-year students, especially Year 1-3 students, providing them with sufficient guidance from both teachers and parents should be the priority as these students often lack the ability to monitor and reflect on learning progress. In particular, these students would prefer more real-time interaction with teachers, tutoring from parents, and regular online practice examinations. These forms of guidance could help early-school-year students to cope with involuntary online learning, and potentially enhance their experience in future online learning. It should be noted that, early-school-year students demonstrated interest in intelligent monitoring and feedback systems for learning.

Additional research is required to understand whether these young children are capable of understanding and using learning analytics that relay information on their learning progress. Similarly, future research should also investigate whether young children can communicate effectively through digital tools as potential inability could hinder student learning in online group activities. Therefore, the design of online learning for early-school-year students should focus less on independent learning but ensuring that students are learning effective under the guidance of teachers and parents.

In contrast, group learning and peer interaction are essential for older children and adolescents. The delivery of online learning for these students should focus on providing them with more opportunities to communicate with each other and engage in collaborative learning. Potential methods to achieve this goal involve assigning or encouraging students to form study groups (Lee, Srinivasan, Trail, Lewis, & Lopez, 2011), directing students to use social media for peer communication (Dabbagh & Kitsantas, 2012), and providing students with online group assignments (Bickle & Rucker, 2018).

Special attention should be paid to students enrolled in high schools. For high-school-year students, in particular, students in Year 10-12, we also recommend to provide them with sufficient access to paper-based learning materials, such as revision booklet and practice exam papers, so they remain familiar with paper-based examinations. This recommendation applies to any students who engage in online learning but has to take their final examination in paper format. It is also imperative to assist high-school-year students who are facing examinations to direct their learning efforts better. Teachers can fulfil this need by sharing useful learning resources on the learning management system, if it is available, or through social media groups. Alternatively, students are interested in intelligent recommendation systems for learning resources, which are emerging in the literature (Shishehchi, Banihashem, & Zin, 2010; Corbi & Solans, 2014). These systems could provide personalised recommendations based on a series of evaluation on learners' knowledge. Although it is infeasible for situations where the transformation to online learning happened rapidly (i.e. during the COVID-19 pandemic), policymakers can consider embedding such systems in future online education.

6.5. Limitations

The current findings are limited to primary and secondary Chinese students who were involuntarily engaged in online learning during the COVID-19 pandemic. Despite the large sample size, the population may not be representative as participants are all from a single province. Also, information about the quality of online learning platforms, teaching contents, and pedagogy approaches were not collected. It is likely that the infrastructures of online learning in China, such as learning platforms, instructional designs, and teachers' knowledge about online pedagogy, were underprepared for the sudden transition. Thus, our findings may not represent the experience of students who voluntarily participated in well-prepared online learning programs, in particular, the virtual school programs in America and Canada (Molnar et al., 2019; Barbour & LaBonte, 2017). Lastly, the survey was only evaluated and validated by teachers but not students. Therefore, students with the lowest reading comprehension levels might have a different understanding of the items' meaning, especially terminologies that involve abstract contracts like self-regulation and autonomy in item Q17.

7. Conclusion

In conclusion, we identified across-year differences between primary and secondary school students' online learning experience during the COVID-19 pandemic. Several recommendations were made for the future practice and research of online learning in the K-12 student population. First, educational authorities and schools should provide sufficient technical support to help students to overcome potential internet and technical problems, as well as choosing online learning platforms that have been customised for smartphones. Second, customising the online pedagogy design for students in different school years, in particular, focusing on providing sufficient guidance for young children, more online collaborative opportunity for older children and adolescent, and additional learning resource for senior students who are facing final examinations.

The rapid growth of online learning in the K-12 sector would likely to remain or potentially accelerate after the pandemic as the world experienced and acknowledged the accessibility advantages of online learning. However, educational stakeholders should also recognise the potential problems within the current online pedagogy design and taking small steps to address these problems for children at different stages of their education. As learning from a distance become more familiarised and accepted by the general public, it is also imperative to continue the exploration of the best practice in online education for students in different ages, cultures, and socioeconomic statuses.

References

Aesaert, K., Van Nijlen, D., Vanderlinde, R., & van Braak, J. (2014). Direct measures of digital information processing and communication skills in primary education: Using item response theory for the development and validation of an ict competence scale. *Computers & Education*, *76*, 168–181.

Agung, A. S. N., Surtikanti, M. W., Quinones, C. A., et al. (2020). Students' perception of online learning during covid-19 pandemic: A case study on the english students of stkip pamane talino. *SOSHUM: Jurnal Sosial Dan Humaniora*, *10*(2), 225–235.

Anderson, T. (2003). Getting the mix right again: An updated and theoretical rationale for interaction. *The International Review of Research in Open and Distributed Learning*, *4*(2).

Appana, S. (2008). A review of benefits and limitations of online learning in the context of the student, the instructor and the tenured faculty. *International Journal on E-learning*, *7*(1), 5–22.

Bączek, M., Zagańczyk-Bączek, M., Szpringer, M., Jaroszyński, A., & Wożakowska-Kapłon, B. (2021). Students' perception of online learning during the covid-19 pandemic: a survey study of polish medical students. *Medicine*, *100*(7).

Barbour, M. K. (2013). The landscape of k-12 online learning: Examining what is known. *Handbook of distance education*, *3*, 574–593.

Barbour, M. K., Huerta, L., & Miron, G. (2018). Virtual schools in the us: Case studies of policy, performance and research evidence. In *Society for information technology & teacher education international conference* (pp. 672–677).

Barbour, M. K., & LaBonte, R. (2017). *State of the nation: K-12 e-learning in canada, 2017 edition.*

Barbour, M. K., & Reeves, T. C. (2009). The reality of virtual schools: A review of the literature. *Computers & Education*, *52*(2), 402–416.

Basuony, M. A., EmadEldeen, R., Farghaly, M., El-Bassiouny, N., & Mohamed, E. K. (2020). The factors affecting student satisfaction with online education during the covid-19 pandemic: an empirical study of an emerging muslim country. *Journal of Islamic Marketing*.

Berge, Z. L. (2005). *Virtual schools: Planning for success*. Teachers College Press, Columbia Univ.

Bickle, M. C., & Rucker, R. (2018). Student-to-student interaction: Humanizing the online classroom using technology and group assignments. *Quarterly Review of Distance Education*, *19*(1), 1–56.

Broadbent, J., & Poon, W. L. (2015). Self-regulated learning strategies & academic achievement in online higher education learning environments: A systematic review. *The Internet and Higher Education*, *27*, 1–13.

Calderoni, J. (1998). *Telesecundaria: Using tv to bring education to rural mexico* (Tech. Rep.). Mexico: The World Bank.

China Internet Network Information Center. (2020). *The 45th statistical report on internet development in china.* Retrieved 2020-07-20, from http://www.cac.gov.cn/2020-04/27/c_1589535470378587.htm

Cisco. (2018). *Bandwidth requirements for meetings with cisco webex and collaboration meeting rooms white paper.* Retrieved 2020-09-02, from https://www.cisco.com/c/en/us/products/collateral/conferencing/webex-cloud-connected-audio/white-paper-c11-735650.html?referring_site=REŽpos=1Žpage=https://www.cisco.com/c/en/us/products/collateral/conferencing/webex-meetings/white_paper_c11-691351.html (Library Catalog: www.cisco.com)

Cisco. (2019). *Cisco Digital Readiness 2019.* Retrieved 2020-07-07, from https://www.cisco.com/c/m/en_us/about/corporate-social-responsibility/research-resources/digital-readiness-index.html#/ (Library Catalog: www.cisco.com)

Clark, C., Strudler, N., & Grove, K. (2015). Comparing asynchronous and synchronous video vs. text based discussions in an online teacher education course. *Online Learning*, *19*(3), 48–69.

Claro, M., Preiss, D. D., San MartíN, E., Jara, I., Hinostroza, J. E., Valenzuela, S., . . . Nussbaum, M. (2012). Assessment of 21st century ict skills in chile: Test design and results from high school level students. *Computers & Education*, *59*(3), 1042–1053.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences.* Routledge Academic.

Corbi, A., & Solans, D. B. (2014). Review of current student-monitoring techniques used in elearning-focused recommender systems and learning analytics: The experience api & lime model case study. *IJIMAI*, *2*(7), 44–52.

Crone, E. A., & Konijn, E. A. (2018). Media use and brain development during adolescence. *Nature communications*, *9*(1), 1–10.

Dabbagh, N., & Kitsantas, A. (2012). Personal learning environments, social media, and self-regulated learning: A natural formula for connecting formal and informal learning. *The Internet and higher education*, *15*(1), 3–8.

Garrison, D. R., Cleveland-Innes, M., & Fung, T. S. (2010). Exploring causal relationships among teaching, cognitive and social presence: Student perceptions of the community of inquiry framework. *The internet and higher education*, *13*(1-2), 31–36.

Gašević, D., Adesope, O., Joksimović, S., & Kovanović, V. (2015). Externally-facilitated regulation scaffolding and role assignment to develop cognitive presence in asynchronous online discussions. *The internet and higher education*, *24*, 53–65.

Gašević, D., Zouaq, A., & Janzen, R. (2013). "choose your classmates, your gpa is at stake!" the association of cross-class social ties and academic performance. *American Behavioral Scientist*, *57*(10), 1460–1479.

Gikas, J., & Grant, M. M. (2013). Mobile computing devices in higher education: Student perspectives on learning with cellphones, smartphones & social media. *The Internet and Higher Education*, *19*, 18–26.

Harvey, D., Greer, D., Basham, J., & Hu, B. (2014). From the student perspective: Experiences of middle and high school students in online learning. *American Journal of Distance Education*, *28*(1), 14–26.

Hrastinski, S. (2008). Asynchronous and synchronous e-learning. *Educause quarterly*, *31*(4), 51–55.

Huffaker, D. A., & Calvert, S. L. (2003). The new science of learning: Active learning, metacognition, and transfer of knowledge in e-learning applications. *Journal of Educational Computing Research*, *29*(3), 325–334.

Kauffman, H. (2015). A review of predictive factors of student success in and satisfaction with online learning. *Research in Learning Technology*, *23*.

Kuo, Y.-C., Walker, A. E., Belland, B. R., Schroder, K. E., & Kuo, Y.-T. (2014). A case study of integrating interwise: Interaction, internet self-efficacy, and satisfaction in synchronous online learning environments. *International Review of Research in Open and Distributed Learning*, *15*(1), 161–181.

Lee, S. J., Srinivasan, S., Trail, T., Lewis, D., & Lopez, S. (2011). Examining the relationship among student perception of support, course satisfaction, and learning outcomes in online learning. *The Internet and Higher Education*, *14*(3), 158–163.

Liu, F., & Cavanaugh, C. (2012). Factors influencing student academic performance in online high school algebra. *Open Learning: The Journal of Open, Distance and e-Learning*, *27*(2), 149–167.

Lou, Y., Bernard, R. M., & Abrami, P. C. (2006). Media and pedagogy in undergraduate distance education: A theory-based meta-analysis of empirical literature. *Educational Technology Research and Development*, *54*(2), 141–176.

Malik, M., & Fatima, G. (2017). E-learning: Students' perspectives about asynchronous and synchronous resources at higher education level. *Bulletin of Education and Research*, *39*(2), 183–195.

McInnerney, J. M., & Roberts, T. S. (2004). Online learning: Social interaction and the creation of a sense of community. *Journal of Educational Technology & Society*, *7*(3), 73–81.

Miron, G., & Gulosino, C. (2016). Virtual schools report 2016: Directory and performance review. *National Education Policy Center*.

Molnar, A., Miron, G., Elgeberi, N., Barbour, M. K., Huerta, L., Shafer, S. R., & Rice, J. K. (2019). Virtual schools in the us 2019. *National Education Policy Center*.

Molnar, A., Miron, G., Gulosino, C., Shank, C., Davidson, C., Barbour, M., … Nitkin, D. (2017). Virtual schools report 2017. *Boulder, CO: National Education Policy Center. Retrieved July*, *23*, 2018.

Montag, C., Becker, B., & Gan, C. (2018). The multipurpose application wechat: a review on recent research. *Frontiers in psychology*, *9*, 2247.

Montague, M., & Rinaldi, C. (2001). Classroom dynamics and children at risk: A followup. *Learning Disability Quarterly*, *24*(2), 75–83.

Moore, M. G. (1989). Editorial: Three types of interaction. *American Journal of Distance Education*, *3*(2), 1-7. Retrieved from https://doi.org/10.1080/08923648909526659 doi: 10.1080/08923648909526659

Muilenburg, L. Y., & Berge, Z. L. (2005). Student barriers to online learning: A factor analytic study. *Distance education*, *26*(1), 29–48.

Muirhead, B., & Juwah, C. (2004). Interactivity in computer-mediated college and university education: A recent review of the literature. *Journal of Educational Technology & Society*, *7*(1), 12–20.

Niemi, H. M., Kousa, P., et al. (2020). A case study of students' and teachers' perceptions in a finnish high school during the covid pandemic. *International journal of technology in education and science.*.

Oliver, K., Osborne, J., & Brady, K. (2009). What are secondary students' expectations for teachers in virtual school environments? *Distance Education*, *30*(1), 23–45.

Pardo, A., Jovanovic, J., Dawson, S., Gašević, D., & Mirriahi, N. (2019). Using learning analytics to scale the provision of personalised feedback. *British Journal of Educational Technology*, *50*(1), 128–138.

Ramij, M., & Sultana, A. (2020). Preparedness of online classes in developing countries amid covid-19 outbreak: A perspective from bangladesh. *Afrin, Preparedness of Online Classes in Developing Countries amid COVID-19 Outbreak: A Perspective from Bangladesh (June 29, 2020)*.

Rice, K. L. (2006). A comprehensive look at distance education in the k–12 context. *Journal of Research on Technology in Education*, *38*(4), 425–448.

Shishehchi, S., Banihashem, S. Y., & Zin, N. A. M. (2010). A proposed semantic recommendation system for e-learning: A rule and ontology based e-learning recommendation system. In *2010 international symposium on information technology* (Vol. 1, pp. 1–5).

Song, L., Singleton, E. S., Hill, J. R., & Koh, M. H. (2004). Improving online learning: Student perceptions of useful and challenging characteristics. *The internet and higher education*, *7*(1), 59–70.

Spitzer, D. R. (2001). Don't forget the high-touch with the high-tech in distance learning. *Educational Technology*, *41*(2), 51–55.

Thomas, R. M. (2000). *Comparing theories of child development*. Wadsworth/Thomson Learning.

United Nations Educational, Scientific and Cultural Organization. (2020, March). *Education: From disruption to recovery*. Retrieved 2020-07-06, from https://en.unesco.org/covid19/educationresponse (Library Catalog: en.unesco.org)

Uttal, D. H., & Cohen, C. A. (2012). Spatial thinking and stem education: When, why, and how? In *Psychology of learning and motivation* (Vol. 57, pp. 147–181). Elsevier.

Van Lancker, W., & Parolin, Z. (2020). Covid-19, school closures, and child poverty: a social crisis in the making. *The Lancet Public Health*, *5*(5), e243–e244.

Wang, C.-H., Shannon, D. M., & Ross, M. E. (2013). Students' characteristics, self-regulated learning, technology self-efficacy, and course outcomes in online learning. *Distance Education*, *34*(3), 302–323.

Wang, J., & Antonenko, P. D. (2017). Instructor presence in instructional video: Effects on visual attention, recall, and perceived learning. *Computers in human behavior*, *71*, 79–89.

Wilkinson, A., Roberts, J., & While, A. E. (2010). Construction of an instrument to measure student information and communication technology skills, experience and attitudes to e-learning. *Computers in Human Behavior*, *26*(6), 1369–1376.

World Health Organization. (2020, July). *Coronavirus disease 2019 (COVID-19): Situation Report-164* (Situation Report No. 164). Retrieved from https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200702-covid-19-sitrep-164.pdf?sfvrsn$=$ac074f58$_$2

Yates, A., Starkey, L., Egerton, B., & Flueggen, F. (2020). High school students' experience of online learning during covid-19: the influence of technology and pedagogy. *Technology, Pedagogy and Education*, 1–15.

A. Appendix: Original Survey

This appendix includes the original Chinese survey used in our study.

Q1 请问您的学校所在地区和类别: _____

Q2 请问您的年级:

    (a) 一年级

    (b) 二年级

    (c) 三年级

    (d) 四年级

    (e) 五年级

    (f) 六年级

    (g) 初一

    (h) 初二

    (i) 初三

    (j) 高一

    (k) 高二

    (l) 高三

Q3 请问您疫情期间进行线上学习时，使用下列哪些设备/材料?

    (a) 电视

    (b) 电脑

    (c) 平板

    (d) 手机

    (e) 音频

    (f) 纸质学习材料

Q4 除了听课功能外，请问您还使用过线上教育平台的哪些功能?

    (a) 作业提交

    (b) 回看课程视频

    (c) 班级通知

    (d) 随堂测试

    (e) 线上学科竞赛游戏

    (f) 视频会议

    (g) 班级圈

    (h) 弹幕

    (i) 屏幕共享

    (j) 优秀作业查看

    (k) 讨论

    (l) 课堂发言

    (m) 作业批改反馈

Q5 请问您学习线上课程时间最长的课时约为?

(a) 20分钟及以内

(b) 20-30（含）分钟

(c) 30-45（含）分钟

(d) 45分钟以上

Q6 请问您每天线上学习的时间多长？（移动滑块至对应数量的位置，0-15小时）

Q7 请问以下学习状态，哪一种符合您的情况？

(a) 能专心学习

(b) 在监督陪伴下，能专心学习

(c) 有时能专心学习，有时不能专心学习

(d) 基本不能专心学习

(e) 不适应线上学习

Q8 请问进行线上学习时，您是否需要家人陪伴？

(a) 完全不需要

(b) 有时需要

(c) 完全需要

Q9 请问您喜欢的线上课堂组织形式是？网络直播与录播的界定：*网络直播指教师通过网络组织课堂的同时，制作和发布课堂内容，其信息传播具有及时性；*录播指将影像、声音记录成标准的网络格式进行发布，其信息传播具有延时性；*资源包指与课程内容相关的视音频、文本、学习工具、学习支架、学习方式、辅导答疑测评等组合而成的电子资源包。

(a) 直播

(b) 录播

(c) 资源包

(d) 电视课堂

(e) 直播+录播

(f) 直播+资源包

(g) 录播+资源包

(h) 直播+录播+资源包

(i) 录播+资源包+线上辅导答疑

Q10 请问您学习的线上课程内容包括？

(a) 学科课程新课

(b) 学科课程复习

(c) 音美体劳教育

(d) 专题教育（课外知识、自律活动、学习方法指导等）

Q11 您对于线上学习未掌握的知识点常用哪些办法解决？

(a) 查阅线上资源自主解决

(b) 通过学习平台的视频回放

(c) 教师集中时间线上答疑

(d) 线上随时利用微信、钉钉等社交平台咨询教师

    (e) 同学互相交流

    (f) 暂时放下，待以后解决

Q12 您参与线上学习的课堂互动频率如何？

    (a) 不回答问题

    (b) 偶尔参与回答问题

    (c) 大多数情况下能参与回答问题

    (d) 积极发言，回答问题

    (e) 课堂没有问答环节，没有机会回答

Q13 请问您线上学习时，遇到过哪些主要问题？（限选5项）

    (a) 网络基础资源有限，容易拥堵卡顿

    (b) 线上学习平台体验不好或功能受限

    (c) 与教师沟通不顺畅，问题无法及时解答

    (d) 课后作业设置不合理

    (e) 课程资源质量欠佳

    (f) 长时间观看屏幕，眼睛疲劳

    (g) 要求安装的软件平台过多，容易混淆

    (h) 环境干扰因素多，难以集中学习

Q14 关于以下线上学习行为，请在下面的表格中选出符合您情况的答案。[是/否]

    (a) 是否回看课程视频？

    (b) 是否认真学习老师提供的其他课程资料？

    (c) 是否开展居家自觉自学、自修活动？

    (d) 遇到问题时，是否积极向老师提问？

    (e) 线上完成作业的质量，是否能够达到与线下一样的效果？

Q15 请问您认为线上教育培养了哪些能力？

    (a) 自主学习能力

    (b) 自控能力

    (c) 数字化资源的利用能力

    (d) 表达沟通

    (e) 生活实践

    (f) 其他

Q16 请问您对线上学习以下方面的满意度如何？

	非常满意	满意	一般	不满意
线上课堂直播				
线上课堂录播				
教师线上教学的态度				
教师线上教学水平和效果				
线上学习资源内容				
使用的线上学习平台				
线上学习的总体满意度				

Q17 与实体课堂相比，您认为线上学习有什么优势？

    (a) 能够听到更多名师优质课

    (b) 可以更加方便地回看、复习，帮助理解

    (c) 学习效果更好

    (d) 减轻了学习负担

    (e) 学习自觉性自主性增强

    (f) 可以随时随地学习

    (g) 其他

Q18 与实体课堂相比，您认为线上学习的不足有哪些？

    (a) 不如课堂教学效果好

    (b) 视频课程资源质量参差不齐

    (c) 学习负担加重

    (d) 缺乏师生互动

    (e) 其他

Q19 请问您期待能够有哪些线上活动或体验促进线上学习？

    (a) 老师实时视音频方式的互动、答疑

    (b) 线上小组讨论和合作

    (c) 增加专题教育的内容和课时

    (d) 线上随堂测试或考试

    (e) 智能推荐学习资源

    (f) 学习状态智能监测并反馈、提醒

    (g) 其他

Q20 疫情结束后，您喜欢哪种学习模式？

    (a) 以前的实体课堂学习模式

    (b) 实体课堂学习模式，线上学习资源作为学习资源的补充

    (c) 线上线下混合式学习模式

    (d) 完全线上的学习模式

B. Appendix: Survey Translation

This appendix includes the English translation of the original survey used in our study.

Q1 What is the location and category of your school: _____

Q2 Your grade:

    (a) First Grade

    (b) Second Grade

    (c) Third Grade

    (d) Fourth Grade

    (e) Fifth Grade

    (f) Sixth Grade

    (g) Seventh Grade

    (h) Eighth Grade

    (i) Ninth Grade

    (j) Tenth Grade

    (k) Eleventh Grade

    (l) Twelfth Grade

Q3 Which of the following equipment/materials did you use during your online learning throughout the outbreak?

    (a) TV

    (b) Computer

    (c) Tablet

    (d) Smartphone

    (e) Audio

    (f) Paper-based materials

Q4 Other than the lecture function, which features of the online education platform have you used?

    (a) Homework submission

    (b) Lecture recap

    (c) Class announcement

    (d) In-class test

    (e) Online subject-related competition game

    (f) Video conference

    (g) Intra-class forum

    (h) Live commenting

    (i) Screen sharing

    (j) Viewing homework that achieved an excellent grade

    (k) Discussion

    (l) In-class commenting

    (m) Homework feedback

Q5 What is the longest class time for your online courses?

    (a) Within 20 mins

    (b) 20 - 30 (inclusive) mins

    (c) 30 – 45 (inclusive) mins

    (d) Over 45 mins

Q6 How long do you study online every day? (Move the slider to the corresponding number of positions, 0-15 hours)

Q7 Which of the following learning statuses is appropriate for your situation?

    (a) I can focus on studying

    (b) I can focus on studying under supervision

    (c) I can focus on study sometimes

    (d) I generally cannot focus on studying

    (e) Unadapted to online learning

Q8 Do you need your families accompanies when studying online?

    (a) No need at all

    (b) Sometimes

    (c) Totally needed

Q9 What is the online classroom/learning format that you enjoyed? Definition of webcast and recording: * Webcast refers to the production and distribution of classroom content by the teacher while organizing the classroom through the network, and its information dissemination is timely; * Recording refers to recording images and sounds in a standard network format for release, and its information transmission is delayed; * Resource pack refers to an electronic resource pack that combines video and audio, text, learning tools, learning supports, learning methods, tutoring, quiz, and assessment related to the course content.

    (a) Webcast

    (b) Recording

    (c) Resource pack

    (d) TV lecture

    (e) Webcast + Recording

    (f) Webcast + Resource pack

    (g) Recording + Resource pack

    (h) Webcast + Recording + Resource pack

    (i) Recording + Resource pack + Online tutoring

Q10 What content does your online course include?

    (a) New subject content

    (b) Revision content

    (c) Music, beauty and physical education

    (d) Special education (extracurricular knowledge, self-discipline activities, learning method guidance, etc.)

Q11 What methods do you usually use to learn materials that you didn't understand during online learning?

    (a) Solving independently by searching online

    (b) Re-watch recorded lectures

    (c) Attend Q&A sessions organized by teachers

    (d) Ask teachers by using social platforms

    (e) Communicate with other students

    (f) Leave it for later

Q12 How often do you interact with your classroom in online learning?

    (a) Not answering questions

    (b) Answering questions sometimes

    (c) Answering questions most of the times

    (d) Actively participating and answering questions

    (e) Classes does not have a Q&A session, do not have the opportunity to answer questions

Q13 What major problems did you encounter when studying online? (Limited to 5 items)

    (a) Confusion in setting up the platforms

    (b) Poor experience with online learning platforms

    (c) Poor course design/delivery

    (d) Poor Internet connection

    (e) Disengagement caused by nearby disturbance

    (f) Insufficient communication with teachers

    (g) Eyestrain caused by long staring at screens

    (h) Excessive homework assignments

Q14 Regarding the following online learning behaviours, please select the answer that fits your situation in the form below. (Yes/No)

    (a) Do you re-watch lecture videos?

    (b) Have you carefully studied other course materials provided by your teacher?

    (c) Have you carried out home-based self-study activities?

    (d) When you encounter a problem, do you actively ask the teacher?

    (e) Can the quality of the work done online be as good as offline?

Q15 What skills do you think are developed from online education?

    (a) Self-learning

    (b) Self-regulation

    (c) Utilization of digital resources

    (d) Communication

    (e) Life practice

    (f) Other

Q16 How satisfied are you with the following aspects of online learning?

	Very satisfied	Satisfied	Average	Not satisfied
Webcast				
Lecture recording				
Teachers' attitude				
Teachers' online teaching skills				
Online learning resources				
Online learning platform				
Overall satisfaction				

Q17 What do you think are the advantages of online learning compared to physical classrooms?

    (a) Access to courses delivered by famous teachers

    (b) More convenient to review course content

    (c) Achieve better learning performance

    (d) Less learning efforts are required

    (e) Helpful to develop self-regulation and autonomy

    (f) Can learn anytime and anywhere

    (g) Other

Q18 What do you think are the deficiencies of online learning compared to physical classrooms?

    (a) Less effective than classroom-based education

    (b) Unstable course quality

    (c) Increased learning efforts

    (d) Lack of teacher-student interaction

    (e) Other

Q19 What online activities or experiences do you expect to have that will enhance your online learning?

    (a) Real-time interaction with teachers

    (b) Online group discussion and collaboration

    (c) Increase the content and length of special education

    (d) Intelligent recommendation system for learning resource

    (e) Intelligent monitoring and feedback system for learning

    (f) Other

Q20 After the COVID-19 epidemic, which learning style do you prefer?

    (a) Classroom-based learning

    (b) Classroom-based learning with online resources as supplement

    (c) Blended learning

    (d) Online learning

C. Appendix: Supplementary Results

The uncombined results from cross-tabulating Question 2 with Question 3, 8, 11, 13, 17, 18, 19, and 20.

Table 10

Results on Q3, which surveyed the learning mediums used by students in online learning. All results are in percentages. The results in the column `All` were calculated by taking students of all school years into account. The top 3 results of each school year (i.e., each column) are marked in bold; and the results that are below the corresponding `All` value in the same row are marked with grey background.

School Year	1	2	3	4	5	6	7	8	9	10	11	12	All
TV	**26.57**	**24.81**	**22.53**	**22.37**	**22.45**	21.59	15.62	14.96	13.57	10.85	10.24	8.25	18.64
Computer	**20.45**	**20.69**	**20.96**	**21.68**	**22.78**	23.97	27.30	28.19	28.01	32.81	33.36	34.18	25.43
Tablet	19.32	19.74	20.56	19.08	18.29	16.87	15.05	14.11	12.61	13.67	12.48	13.94	16.78
Smartphone	**83.18**	**83.03**	**83.55**	**84.54**	**86.39**	**87.86**	**87.57**	**89.68**	**90.76**	**92.34**	**93.3**	**92.24**	87.39
Audio	3.85	3.86	4.58	4.58	4.93	4.83	4.80	5.35	5.25	6.14	6.23	5.06	4.94
Paper-based materials	18.02	17.11	16.84	17.56	20.16	**22.1**	**23.62**	**25.91**	**27.06**	**33.92**	**35.42**	**39.62**	23.63

Table 11

Results on Q8, which surveyed to what extent students were accompanied by their families during the online learning process. All results are in percentages. The results in the column `All` were calculated by taking students of all school years into account. The results that are below the corresponding `All` value in the same row are marked with grey background.

School Year	1	2	3	4	5	6	7	8	9	10	11	12	All
Not at all	8.68	17.00	24.01	35.85	46.60	57.29	66.77	74.26	77.71	85.02	88.33	86.63	52.59
Sometimes	63.60	66.63	64.92	57.00	48.69	39.14	30.75	23.67	20.30	13.39	10.21	11.59	40.30
Always	27.71	16.37	11.07	7.15	4.71	3.57	2.48	2.06	1.99	1.59	1.46	1.78	7.10

Table 12

Results on Q11, which surveyed the approaches used by students to master the unlearnt concepts in online learning. All results are in percentages. The results in the column `All` were calculated by taking students of all school years into account. The top 3 results of each school year (i.e., each column) are marked in bold; and the results that are below the corresponding `All` value in the same row are marked with grey background.

School Year	1	2	3	4	5	6	7	8	9	10	11	12	All
Solve independently by searching online	**30.82**	**34.34**	**37.19**	**41.41**	**45.01**	**47.91**	51.31	55.25	57.29	63.94	66.40	66.71	48.20
Re-watch recorded lectures	71.73	71.15	71.21	71.27	72.59	73.28	72.78	71.57	67.84	71.36	71.08	61.65	71.02
Attend Q&A sessions organized by teachers	20.88	23.17	25.42	26.79	27.13	28.13	30.16	29.99	31.32	29.06	30.70	30.10	27.74
Ask teachers by using social platforms	**31.55**	**31.40**	**31.84**	**32.98**	**33.45**	34.97	38.89	39.88	42.81	37.94	39.42	41.26	**36.07**
Communicate with other students	12.15	14.60	19.30	24.02	29.93	**35.71**	**45.53**	**48.78**	**50.11**	**45.57**	**47.58**	**43.89**	**33.98**
Leave it for later	12.59	11.91	11.45	9.72	8.80	7.86	8.02	9.41	10.27	13.42	12.55	12.87	10.33

Table 13

Results on Q13, which surveyed the obstacles encountered by students in online learning. All results are in percentages. The results in the column `All` were calculated by taking students of all school years into account. The top 3 results of each school year (i.e., each column) are marked in bold; and the results that are below the corresponding `All` value in the same row are marked with grey background.

School Year	1	2	3	4	5	6	7	8	9	10	11	12	All
Poor Internet connection	**42.37**	**44.95**	**48.55**	**50.92**	**51.00**	**50.96**	**53.23**	**51.54**	49.62	49.91	50.27	48.66	**49.48**
Poor experience with online learning platforms	23.60	23.99	24.21	23.72	22.75	21.50	21.75	22.61	22.88	24.17	24.57	26.30	23.27
Insufficient communication with teachers	30.14	30.89	30.83	29.08	26.69	25.70	24.58	23.23	22.52	23.40	22.93	22.76	26.37
Excessive homework assignments	4.94	5.85	6.92	7.52	7.75	8.03	9.76	12.27	13.21	16.83	17.79	15.56	9.80
Poor course design/delivery	14.35	15.16	15.12	14.91	14.67	14.68	13.37	14.21	13.83	15.57	15.98	14.49	14.61
Eyestrain casued by long staring at screens	**71.66**	**70.88**	**71.51**	**71.65**	**70.61**	**69.99**	**73.40**	**73.98**	**74.83**	**77.64**	**79.26**	**80.71**	**73.15**
Confusion in setting up the platforms	18.83	19.33	22.35	23.36	22.84	21.40	20.02	19.93	18.71	19.61	20.67	23.06	20.86
Disengagement caused by nearby disturbance	**51.90**	**48.00**	**44.06**	**39.00**	**34.49**	31.94	32.50	34.58	37.39	43.30	43.89	48.29	39.86

Table 14
Results on Q17, which surveyed the advantages of online learning perceived by students. All results are in percentages. The results in the column `All` were calculated by taking students of all school years into account. The top 3 results of each school year (i.e., each column) are marked in bold; and the results that are below the corresponding `All` value in the same row are marked with grey background.

School Year	1	2	3	4	5	6	7	8	9	10	11	12	All
Access to courses delivered by famous teachers	46.07	47.75	49.16	49.86	51.12	50.91	45.24	42.18	41.01	37.40	39.12	40.77	45.86
More convenient to review course content	68.53	68.78	69.34	71.53	73.93	75.70	78.69	78.01	76.70	80.42	80.53	75.74	74.48
Achieve better learning performance	11.24	14.96	19.34	22.69	24.66	23.99	21.74	19.73	17.92	15.97	15.52	13.56	19.11
Less learning efforts are required	11.10	13.25	15.41	18.19	20.00	21.56	18.91	18.78	16.61	17.32	16.63	12.59	17.04
Helpful to develop self-discipline and autonomy	28.59	31.76	34.02	37.01	41.64	45.32	49.93	47.25	43.47	41.98	42.61	36.47	40.29
Can learn anytime and anywhere	56.98	55.05	53.16	52.67	52.95	53.87	51.49	53.42	53.21	57.57	58.11	55.38	54.12
Other	11.26	10.01	9.92	8.86	8.01	7.00	6.95	7.72	7.77	5.92	5.60	6.55	8.14

Table 15
Results on Q18, which surveyed the disadvantages of online learning perceived by students. All results are in percentages. The results in the column `All` were calculated by taking students of all school years into account. The top 3 results of each school year (i.e., each column) are marked in bold; and the results that are below the corresponding `All` value in the same row are marked with grey background.

School Year	1	2	3	4	5	6	7	8	9	10	11	12	All
Less effective compared to classroom-based education	76.81	74.04	70.06	66.87	65.24	65.64	65.98	66.85	68.05	67.51	66.98	68.18	68.43
Unstable course quality	24.88	26.14	27.15	26.60	26.26	26.97	26.41	28.55	28.87	32.09	34.03	33.49	27.86
Increased learning efforts	17.46	16.80	18.14	16.90	16.48	16.38	19.81	22.88	23.72	26.46	28.83	27.66	20.09
Lack of teacher-student interaction	72.58	69.12	64.04	61.39	59.84	60.34	60.43	57.36	55.11	57.47	55.03	53.97	61.03
Other	8.52	8.84	10.44	11.48	11.81	10.96	11.69	12.57	12.46	11.12	10.71	10.95	11.02

Table 16
Results on Q19, which surveyed the activities expected by students for future online learning. All results are in percentages. The results in the column `All` were calculated by taking students of all school years into account. The top 3 results of each school year (i.e., each column) are marked in bold; and the results that are below the corresponding `All` value in the same row are marked with grey background.

School Year	1	2	3	4	5	6	7	8	9	10	11	12	All
Real-time interaction with teachers	59.23	60.51	60.49	59.43	57.86	55.74	51.77	49.91	49.74	46.79	47.48	45.58	54.53
Online group discussion and collaboration	22.77	26.34	30.77	35.73	40.66	43.65	46.06	43.72	42.65	39.60	37.63	34.72	37.63
Increase the content and length of special education	26.93	28.69	28.72	29.22	30.03	30.53	30.16	29.99	29.86	28.33	28.69	27.67	29.18
Regular online practice examinations	36.77	38.33	36.98	36.12	34.67	34.54	32.46	30.27	30.88	22.15	22.37	23.52	32.65
Intelligent recommendation system for learning resource	24.17	24.83	26.57	29.23	31.21	32.90	34.29	37.06	37.38	42.53	42.88	40.56	32.84
Intelligent monitoring and feedback system for learning	32.65	32.80	32.72	32.39	32.28	32.01	32.61	33.22	32.76	32.68	33.83	33.14	32.71
Others	14.05	12.39	12.01	11.20	10.70	10.07	10.27	11.17	11.20	9.05	8.57	9.37	10.88

Table 17
Results on Q20, which surveyed the formats of teaching and learning preferred by students in the post COVID-19 era. All results are in percentages. The results in the column `All` were calculated by taking students of all school years into account. The results that are below the corresponding `All` value in the same row are marked with grey background.

School Year	1	2	3	4	5	6	7	8	9	10	11	12	All
Classroom-based learning	51.52	52.23	53.74	54.80	55.23	54.64	51.28	48.16	45.02	36.33	33.76	36.28	49.40
Classroom-based learning with online resources as supplement	37.79	35.66	32.65	30.89	29.35	29.62	30.97	32.82	35.41	39.25	42.20	41.90	33.84
Blended learning	8.40	8.53	8.60	8.64	9.28	10.02	11.99	13.28	14.54	19.70	19.59	18.23	11.78
Online learning	2.29	3.57	5.02	5.67	6.14	5.71	5.77	5.73	5.03	4.72	4.45	3.59	4.98