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Educational technologies in China

*Pre- and post-pandemic
lessons*

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Abstract

China is leading in the application of new digital technologies in education. The market is young, albeit highly competitive, as parents willingly adopt any technological innovation that could help their children, and schools as well, since they are judged on their pupils' success. To foster such a flourishing, there is a wealth of available data under a loose regulatory framework, growing technical expertise and massive public funding and hands-on support. However, structural barriers for educational technologies do exist, such as the pre-eminence granted to admission exams for students above anything else, or an insufficient critical mass of AI talent and deployment. Aware of these limitations, the Chinese administration promotes changes in local education systems that are later extended nationally if they prove to be successful. What happened to the education field during the Covid-19 confinement in China encompasses a vibrant display of public and private initiatives that led to what every expert called a 'boom time' for educational technologies. This report presents in detail the educational technologies ecosystem in China and, from there, analyses the learning outcomes of the pandemic days and potential learnings of significance to Europe. Thus, for instance, China's pursuit of decreasing the education divide between areas lacking infrastructures and urban zones could create economies of scale for affordable and technologically advanced innovations that can be inspirational for Europe.

Contents

Abstract.....	3
Executive summary.....	6
Acknowledgements.....	11
Authors.....	11
Background.....	12
1.1 Education system.....	12
1.2 Context Culture and society.....	13
1.3 Context Economics and policy.....	14
1.4 Objectives and structure of this study.....	14
Methodology.....	16
2.1 Definitions.....	16
2.2 Innovation ecosystem.....	16
2.3 Sources of information and validation.....	17
Policies.....	18
3.1 EdTech development plans.....	18
3.2 Public EdTech-related projects.....	19
3.3 Educational policies and reforms.....	19
3.4 Talent cultivation.....	21
3.5 Online education regulation.....	21
3.6 Code of conduct for teachers.....	22
3.7 Ethics & privacy.....	22
EdTech market in China.....	24
Analysis of EdTech projects.....	26
5.1 Advanced education.....	26
5.2 In-class.....	29
5.3 Beyond classes.....	30
5.4 Support for the education system.....	34
EdTech during the pandemic.....	37
6.1 The institutional response.....	37
6.2 Platforms and resources.....	39
6.3 Teachers' perspective.....	40
6.4 Learning outcomes.....	41
6.5 Students' perspective.....	42
6.6 Effects on families.....	44
Conclusions.....	46
7.1 China leading.....	46
7.2 Drivers of EdTech.....	46

7.3 Structural limitations.....	46
7.4 Permanent change and experimentation.....	47
7.5 Learning opportunities.....	47
7.6 Conclusions from EdTech during the pandemic.....	48
7.7 Potential learnings from China.....	48
References.....	51
Annex 1. Code of conduct for teachers.....	55
Annex 2. Questionnaire for interviews.....	56
Annex 3. Online resources used in China during the pandemic.....	57

Executive summary

Background

The education system in China – the largest public system in the world – is divided into the usual three areas of primary, secondary and university/vocational education. Every aspect of its current implementation revolves around the exams for entry to secondary school, the *zhongkao*, and to enter university, the *gaokao*. The latter is the most competitive exam in the world with close to 10 million students competing every year for a position in any of the top universities in China. The exam is not only important for prestige and the job opportunities that a degree from one of these universities can provide, but also because it can help update the student's residence permit, allowing them to move to one of the tier one cities in China. Therefore, the *gaokao* is seen as the key element for social progress and the families of the students provide all possible means to ensure their offspring have the best opportunities to tackle it. Schools and academies also compete to prove that they provide their students with better chances for the *gaokao*.

In fact, in China's culture it is generally considered that education provides the prime opportunity to obtain a better position in life. Therefore, families are ready for additional spending on education compared to other necessities. The social environment also encompasses a large and young market, eager for technological novelties that enable the rapid commercialisation of innovations, especially if they provide an edge in terms of educational opportunities.

There is also strong support from the government as an investor, a consumer of digital technologies and a provider of access to key data for companies with favourable conditions. In addition, the administration typically conducts many different experiments on new policies and developments at local level that, if satisfactory, are extended across the country. Together with distributed responsibility, this creates an environment where local and regional governments compete to provide the best results possible within the planned top-down policies. This same scheme has occurred during and after the Covid-19 pandemic. Within national guidelines, local authorities were provided room for their own decisions on providing the best technological support for education.

Last but not least, China requires a shift towards innovation – and therefore education in innovation – as a panacea for increasing both the quality of products and productivity, expanding internal consumption as a means to reduce dependence on external markets whilst adding value to its economy. Learning to innovate requires critical thinking, imagination, readiness for change, open-mindedness and a high tolerance for uncertainty. However, its implementation addresses the contradiction of bringing together culture and societal values – that is entrepreneurial and resilient – with the top-down policies from the Communist Party of China (CPC).

Methodology

For the purpose of this document, EdTech is simply considered as the use of digital technologies in and around the education system. The study uses the framework of authors' own reviews of an asymmetric Triple Helix innovation ecosystem. It essentially consists of a national model that takes into account the dynamic relations between industry, university and administration at different levels, and provides an approach for integrating bottom-up initiatives through the regional and local administrations with top-down plans. The main objective of the top-down approach typical of China is a type of 'social engineering' aimed at achieving a 'harmonious and moderately prosperous socialist society'.

This study uses the following sources of information: i) desk research from Chinese and foreign analyses of the education system in China and new technologies; ii) authors' direct experiences in the education system in China; iii) interviews with Chinese students, parents and education professionals before and after the Covid-19 pandemic; iv) visits to schools and universities; and v) author participation in the innovation ecosystem in China. The observations in the study were discussed with technology and education specialists at several events.

Policies

The Next Generation Artificial Intelligence Development Plan (NGAIDP) outlines China's strategy to become the leading AI power in both research and deployment by 2030. It advocates incorporating AI in to virtually all aspects of life, including 'intelligent education'. Following the NGAIDP's release, Chinese tech companies have secured public support and investor funding for various AI projects, several of which are being tested in Chinese schools.

Further public plans include improving AI teaching and research at university level, introducing AI education at primary and secondary school level and building demonstration zones to showcase innovation and best practices of AI-integrated education services.

Reforms of the education system have also started with the aim of moving from abstruse and passive learning to more balanced and elective learning, providing not only essential knowledge but also skills for lifelong learning and problem-solving. However, teachers remain sceptical as to whether the new guidelines will have the desired effect, especially if schools continue to be graded primarily on test scores for university admissions.

Within these reforms, recently issued plans strengthen traditional Chinese cultural education while adding robot design & making, STEAM studies, data management & analysis and artificial intelligence (AI) subjects into the general technology and information technology curriculum. They also aim to stop the evaluation of middle schools based on how many of their students go on to enrol at good high schools, for the first time considering an education curriculum based on competences such as cooperative teamwork and project-based learning. The objectives also include improving the quality of classroom teaching so students do not need to work in excess after classes, supervising and minimising the presence of unapproved content, regulating and supervising online education and establishing a code of conduct for teachers.

New technology ethics and children's privacy, issues previously neglected, have shyly started to surface in the discussion on new regulations and their pending enforcement.

In addition, President Xi declared at the International Conference on AI and Education in May 2019 that China is willing to work with other countries in discussing issues related to AI and innovative education adaptation amid AI's rapid development.

During the pandemic crisis, policies in China primarily consisted in providing all the possible means for online education. As soon as the pandemic was under control, policies consisted in recovering conventional classes as much as possible, since the combination of parents' work commitments, lack of home space and means and difficulties in controlling education made full online education undesirable.

EdTech market

China's online learners reached 172 million in 2018, among which 142 million are learning via mobile devices, with growth rates of 10.7% and 19.6% respectively, with annual expenditure for online K-12 education per capita of RMB¹ 6,000.

In 2018, the total investment in EdTech in China reached approximately €4 billion, which is almost double the 2017 total. The two largest sub-sectors in EdTech in China are K-12 education and language learning; however, the STEM education sector is the fastest-growing sector.

EdTech applications

The EdTech applications currently in place in China can be divided into (i) advanced education, typically for STEM education; (ii) in-class; (iii) additional education beyond regular classes; and (iv) support for the education system.

In the case of advanced education, China is going through a process of transformation in primary and secondary education related to technology. It follows its usual approach of conducting trials in schools, evaluating their results under the lenses of technological progress, societal harmony and socialism with Chinese characteristics and, if successful, scaling up to other schools. In private education, an increasing number of start-ups aim at providing young students with advanced education in programming (visual programming), robotics, artificial intelligence and Internet of Things (IoT). There are also proposals to use new technologies such as VR and 5G in the education process with the aim of providing interactive education. In the case of China, developing and rural regions still struggle for quality education and it is expected that the combination of 5G and interactive education will help to reduce the gap.

Current EdTech being trialled in class includes video cameras, face recognition, drones and brain headsets to ascertain the students' level of attention and provide this information to the professor in real time and to parents through mobile applications. It uses deep learning for image and pattern recognition and classification. The data is used to generate a student's performance index. Some solutions are also able to read students' notebooks. Teachers and experts question the extent to which facial and pattern recognition systems can improve student performance. Experts say there are many technological, legal and moral barriers to overcome before this type of recognition can be widely deployed in Chinese education. However, AI is already being

¹ Exchange rate of RMB 7.9 to EUR 1 at the time of writing this report.

introduced, leading experts to agree that regulations on the technology urgently need to catch up. In any case, the use of biometric information, so far, lacks a clear regulation in China, and schools have not typically asked for consent from students or their parents. In addition, parents are supporters of a technology that allows them to know more about their children. The trials also respond to the Chinese belief that a student's attention and discipline are main ingredients for success.

One special feature of China's education market is after-school institutions. These are organisations that are separate from a student's regular school, which provide supplementary education to students of all ages. Because of China's education system, more than half of the students will choose to take after-school tutoring classes, especially before taking the university entrance exam. Therefore, EdTech beyond classes is an extension, a complement and/or an alternative to these after-school institutions and are mostly based on apps and distance-learning applications to typically improve students' knowledge of English and maths. They use artificial intelligence to provide a tailored approach to each student and convert text-to-speech and vice versa. Some of the start-ups in this field in China have already acquired unicorn status.

Finally, EdTech in China is expected to greatly improve the efficiency of educational organisation. Technologies to support education systems include smart campus/school management, information security systems, cloud platforms, distributed multimedia learning resources, teaching support systems, education software as a service (SaaS) and instant feedback systems. They include processes such as registration, access control, surveillance and even genetic tests to detect intellectual abilities.

Conclusions: (I) EdTech status

China is a country leading in the application of new digital technology in most of the B2C sectors, including education. As a result, competition for education technological innovations in China is fierce, and parents and schools are willing to pay or adopt any application that could help their children. Thus, China is the country where some of the most advanced experiments into the usage of EdTech are happening and, as a logical consequence, is the place from which some of the key implications of the implementation of education technology can be learnt and understood as well as learning from both mistakes and successes.

In fact, the overall result can be summarised as six drivers of China's implementation of EdTech: i) an abundance of data; ii) a loose framework to access and exploit data from users; iii) new entrepreneurship with companies aligned with national interests; iv) growing technical expertise; v) a young market eager for technical novelties that could provide an edge in education; and, last but not least, vi) considerable public funding and support.

However, general implementations of new technologies in China face barriers such as patchy implementation, a lack of standards and compatibility of solutions, administrative shortcomings, technological limitations and unclear guidance. In addition, in the case of education, there are additional structural limitations related to the still predominant legacy approach to education; the pre-eminence of the results of admission exams for students, above anything else; the reluctance to educate in critical thinking skills required for innovation; the lack of enough amount of AI expertise; and the lack of means to provide it locally.

The government, aware of these limitations, promotes changes in the education system that, initially, take shape as local experiments, extending nationally at a later date if successful. The majority of advanced education and in-class applications are still in the first stage of trials, while, beyond classes EdTech is being reformed to become orderly mainstream as these conclusions are written. The applications to support the education system have already been extended as they are felt as just the implementation within the education sector of already existing solutions used in other domains (like work, e-commerce...). In addition, there are now new plans for the reform of the education curriculum at all levels with provinces and cities eager to implement them and gain the advantages of first movers in the attraction and creation of talent.

Conclusions: (II) Possible avenues of mutual learning

China has developed sound education infrastructures, connecting classrooms and deploying digital devices and even content with 5G, virtual reality, robotics, IoT, and eventually linking with schools in remote areas. However, infrastructures and equipment to support tasks related to surveillance, access control, automation or real-time monitoring of students within classes appear controversial from a European perspective.

Other avenues of mutual learning would be related to helping education institutions, teachers and learners to acquire digital skills and methods and validate them. This is a common challenge in China and the EU. The development of exchanges, frameworks, platforms, methods and validation schemes could be inspirational for both.

China enjoys a head start and a large market in the ‘beyond classes’ segment, namely in foreign languages and software programming. Mobilising all stakeholders (teachers, learners, families, economic and social partners) to change the role of digital technology at education institutions seems to be a common issue both in China and the EU. Therefore, there is a potential source of mutual learning.

Open education resources (OER) are another field of education innovation that is fostered widely (Inamorato dos Santos, 2019), also in China, although OER in China can be restricted by different administrations. Nevertheless, the use of OER in adult education might be more promising in China as there is a prevalent attitude towards the relevance of lifelong learning for career development, of self-improvement and to stay competitive in the job market. In addition, the regulatory framework for adult online learning is less restrictive than that for compulsory education. Adult education could cover degree education, MOOCs, lifelong learning – an area of high expertise for the EU – and foreign language learning.

In addition to these objectives for innovating education in the EU, another area for mutual learning could be adaptive education with the help of AI, in particular for those students in need of additional support from tutors. Here, goals of education equality, irrespective of location and income, together with enhanced quality and reduction of costs facilitated by EdTech are of interest to both China and Europe.

Conclusions: (III) Learnings from China’s experience of EdTech

Potential learnings of significance to Europe from the experiences of EdTech in China firstly come from the misalignment between parents and education systems and children in some situations generated by the use of these technologies and that, therefore, seem to ask for some type of regulation or at least delimitation of boundaries between stakeholders.

China has declared its interest in cooperating to set EdTech evaluations with other countries. However, the combination of dissimilar objectives between China and other jurisdictions, and its interest in developing its own path in technology, has so far resulted in EdTech applications in China developing relatively independently.

Another finding of interest is that China is embarking on a combination of technology and human resources to try to reduce the education divide between poverty-stricken/lack of infrastructure areas and more affluent (usually urban) zones. Because of the vast size of this market in China, it is expected that Chinese providers will issue affordable and technologically advanced innovations that could be of interest elsewhere.

To this regard, currently, China’s EdTech is most developed in the areas of image, face, text and voice recognition, together with their supporting techniques, such as machine and deep learning. It is true that, in general, China’s pursuit of intelligent education still emphasises standardised learning and testing, making a progressive pedagogical system based on new digital technologies difficult. However, at the same time, China’s interest in education and its combination with technology is much more open to new innovations, and that if these innovations succeed, they will be rapidly extended.

Looking into China’s leading applications based on adaptive learning supported by technology, they can be effective at understanding exactly what students know and do not know, but they pay less attention to what they want to know or how they learn best. If the pace of learning is personalised, students with different abilities could be allowed different amounts of time to learn the same material. This is an area where technology is already happening in China in particular. If the path is personalised, students might be given different motivations to reach the same objectives and offered the material in different formats. If the destination is personalised, students can choose the real-world goal for their education. Current implementation of EdTech in China is more characterised by bringing all students in the same standardised position and training students on structured knowledge.

Overall, among the possible uses of AI for teaching transversal skills such as collaboration and teamworking, creativity and imagination, critical thinking and problem solving, the focus for advanced EdTech in China is predominantly on problem solving skills.

Conclusions: (IV) Learnings from China’s experience of EdTech during the pandemic crisis

Although there was great enthusiasm of the rapid shift to online learning by the Chinese education system during the pandemic crisis, the main objective is that the educational activity returns to offline activity as soon and as much as possible. The main reasons are educational (online education less efficient than in-person tuition, difficulties in the assessment processes), social (loss of sociability), cultural (evaluating learning outcomes, equal opportunities, competition) and economic (parents need to work all day).

The learning outcomes from the pandemic can be contemplated from different perspectives. From the institutional perspective, China succeeded considerably in the shift to online education as a substitutive/emergency/complementary educational technology. After the shock and some initial confusion, a rapid response through a coordinated initiative between ministries and internet and mobile providers allowed almost any of the targeted 200 million students to connect and learn from anywhere, at any time. This experience would be used in the future to consider online education as a viable alternative, in specific cases, to reduce education-related costs while preserving quality. From the teachers' perspective, the most important issues were their need for training and an adaptation period and the lack of interaction with the new technology versus the real classroom. Plain video conferencing tools were of little help to students and teachers, as interaction was limited, and students were likely to get distracted. Tools that allowed for features such as 'raising hands', sharing the screen, conducting polls, drawing on the screen, sharing documents and co-editing functions were preferred by both students and teachers. From the students' and families' perspective, main issues were related to the parents' pressure on students because of upcoming exams. According to the scores of the *gaokao*, students' grades were similar to previous years as they were kept busy by their parents by taking extracurricular online classes or by accessing online educational content through their mobile devices while quarantining at home. There was, probably, also some extra help with the evaluation to minimise the consequences of this troubling year. At the same time, students reported to have easily adapted to the online tools – more easily than their teachers – and have become more aware of new methodologies and that beyond entertainment, they can also use their devices for educational purposes.

From an EdTech perspective, online learning in China will continue to grow as parallel and complementary education. It has complemented the successful return to the classrooms in September 2020. Technologically, the pandemic has quickened the pace of cloud adoption, both to support near-term activity and to increase agility to withstand future challenges. In the mid- to long-term, experts suggest that the road forward is the merge between offline and online education, creating an opportunity for the EdTech China ecosystem to export this model globally. A blended education is also perceived in the European Union as a future model of education (Di Pietro, G. et al., 2020).

In summary, the effective approach to the pandemic, the implementation of the combined policies of the regional administrations, their positive competition and the guidelines delivered by the Ministry of Education showcased a rather entrepreneurial perspective on education where many attempts and actions were put to test in practice. There were policies to incentivise online education, to pool resources, to enhance the support for companies to launch new applications in EdTech, to free relevant educational content and to ensure equal opportunities independently of the location and family income. The best practices were rapidly supported and exchanged. An ample majority of students benefitted from this combination of policies, although students with a lack of resources faced increased difficulties during the pandemic and the gap between more and less affluent regions might have widened.

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Background

It is only possible to fully understand the status of new technologies in and around the education system in China by providing some background information on the particularities of this education system, the perception of society and culture on education and the economic and policy context.

1.1 Education system

China has the world's largest education sector and the largest state-run education system, with 223,283 primary schools, 11,202 vocational secondary schools, 65,645 high schools, 2,688 universities and 238 million students – 176 million in secondary education – according to 2019 figures from the Ministry of Education. It is also the oldest system in the world, starting about 1600 BC.

Nowadays, standard education is mostly state-run, with moderate private involvement². City, district and county-level administrations³ are the main bodies responsible for school education, whilst the provincial administrative level is in general responsible for higher education⁴. The Ministry of Education oversees education in the country and guides the reforms with legislation, general budget allocation and administrative mechanisms. Policies elaborated by the executive set general goals and are then adjusted by local education authorities – including budget amendments – departments and bureaux of education, who generate practical guidelines for implementation.

The education system in China is divided into the usual three areas of primary (elementary), secondary (middle and high schools) and university/vocational education (tertiary education)⁵. Compulsory education is nine years (6 + 3 years). As of 2019, China's student population remains stable at about 19% of the total population. National expenditure in education is more than 4% of the GDP. Funding allocated for students' education in China has increased consistently since 2011, growing from USD 1,805 in 2011 to USD 2,110 in 2015, while the student-teacher ratio in public schools across all grades has decreased from approximately 20:1 in 2006 to 16:1 in 2016. It is also an extremely competitive⁶ and dynamic system, and just to mention one figure, the number of universities increased by 768 in the decade from 2007 to 2017 alone. It is also worth noting that 97.6% of primary and middle schools have an internet connection⁷.

The education system also faces considerable challenges depending on geography. Students living in eastern China have more educational resources than those from western provinces, as eastern cities are wealthier and can allocate more. Primary school students make up the largest segment. Whilst in western provinces the overall population is lower, this is where the highest concentration of primary students reside. Higher education institutions are concentrated in the more affluent, coastal regions of East China. In general, the quality of the learning environment at basic levels of education needs to be improved. At compulsory levels of education, there are on average 375 children per class in primary school and 48.8 in middle school, while the OECD averages are 20.7 and 23.0, respectively (OECD, 2019).

Arguably, a key feature of the current education system in China is that every aspect of primary and secondary education revolves around the exams for the move from middle school⁸ to high school, or technical and vocational schools, and from high school to university entry – the well-known National Higher Education Entrance Examination,

² More than half of children enrolled in pre-primary education attend private institutions (OECD, 2019).

³ The traditional administrative division of China has three de jure levels of government, although there are five de facto levels of local government: the provinces (including the provinces themselves, the autonomous regions, the municipalities, and special administrative regions), the prefectures, the counties, the townships and the villages.

⁴ Some key universities are directly dependent on the national government and not on provinces or municipalities.

⁵ In 2017, 2% of Chinese tertiary students were enrolled abroad, on par with the OECD average. However, they made up 23% of total incoming students in OECD countries. English-speaking countries were the most popular destinations: 35% of international students from China were enrolled in the United States, 14% in Australia and 10% in the United Kingdom (OECD, 2019).

⁶ A phrase typical of murals in schools across China talks about 'thousands of soldiers trying to cross a small bridge' ('千军万马过独木桥'), reminding students of the difficulties and the effort needed to succeed in education and in life.

⁷ And general internet coverage for 96% of the population, mostly mobile/wireless in extreme rural areas, where most of the limited connectivity lies.

⁸ In this exam, that is the *zhongkao*, students are tested on Chinese, English, mathematics, physics and chemistry.

popularly called *gaokao*⁹. The latter is the most competitive exam in the world with close to 10 million students competing every year for a position in any of the top universities in China. A diploma from one of these top universities is worth far more than one from a mid-tier institution. China drastically expanded its higher education system in 1999, and the number of students who successfully passed the *gaokao* shot up from 1 million in 1998 to 8 million in 2018, while the pass rate went up from 34% to 81%. Therefore, it is no longer enough to simply get a university degree, and slots at elite universities are more valuable than ever. In addition, the exam is not only important for prestige and the job opportunities that a degree from one of these universities can provide, but also because it can change the *hukou* (residence permit) of a student allowing them to move into one of the tier one cities in China, in particular Beijing and Shanghai. Therefore, the *gaokao* is seen as the key element for social progress¹⁰. Families provide all possible means to ensure their offspring have the best opportunities to tackle it¹¹. Schools and academies also compete to prove that they provide their students with better chances for high marks in the *gaokao*.¹² In short, the *gaokao* is a life-changing exam and this is how it is perceived by China society.

Another relevant feature of the education system in China is its state of almost permanent change as later described in detail. There is a project to reform the education curriculum at all levels, to essentially move towards a more balanced and elective curriculum, providing essential knowledge as well as skills for lifelong learning and problem-solving, and with participation and oversight of the central government, local authorities and schools. In particular, China wants more high schools to offer the elective courses known as *zouban* in order to better meet students' needs and interests. Local schools have been experimenting with *zouban* electives to increase student choice for decades, but the system has become more widespread in recent years as provinces and municipalities continue to add elective sections to their university entrance examinations. Now that the system has been tested positively, the central government has explicitly endorsed it and encouraged local authorities to implement the model. According to the Ministry of Education the goal of high school studies will no longer be simply getting into a university, but also helping students to figure out their interests in life and targets for their future career. However, there exists some scepticism as to whether the new guidelines will have the desired effect, especially if schools continue to be graded primarily on test scores for university admissions.

Three final notes of interest are that multilingualism is now the new normal in China's schools (English, but increasingly other languages such as Spanish or German); international schools (international branches of local schools or purely international schools) are more flexible and open to innovation and leaders in STEAM¹³ education; and that the higher education system continues to further implement its global strategy to enhance the competence of its students, its high-end research, the number and quality of international exchanges and its global impact.¹⁴

1.2 Context: Culture and society

An initial contextual element for the education system consists of a culture that considers education of utmost importance for a better life. Therefore, families are prepared to make great financial efforts. According to authors' estimations, about one fifth of their disposable income is spent on their children's education¹⁵.

⁹ A popular expression in China summarises it as 'the one test defining the rest of your life'.

¹⁰ According to the Ministry of Education, the *gaokao* has two main functions: firstly, it identifies talent no matter the social or economic background of the student; secondly, it provides a standardised set of skills that raises the bar for the entire society.

¹¹ Among the many pieces of evidence regarding the relevance of *gaokao* for families is that it is relatively popular for mothers (primarily) to ask for a one-year leave to help her offspring with the study required for the exam.

¹² Strictly speaking, it is also possible to access top universities in China through the *Independent Freshman Admission Program* (IFAP), a scheme created in 2003 to allow top universities to directly recruit outstanding candidates who excel in one area but struggle in comprehensive exams like the *gaokao*. However, this system is being criticised due to a lack of standardisation compared to the *gaokao*.

¹³ STEAM refers to Science, Technology, Engineering, Arts and Mathematics education.

¹⁴ In 2018 more than 492,000 international students studied in China, and in the 2019 edition of the QS World University Rankings 6 mainland China universities made it into the world's top 100. In 2017, China launched the Double World-Class Project with the aim of reaching 42 world-class universities and 456 world-class disciplines in 95 universities by the middle of the century. China's top 10 universities produced 428,000 papers in the period 2014-2018, while the top 10 US universities produced about 444,000.

¹⁵ Official statistics in China show that 12% of disposable income is spent on education in the case of urban households and 14% in the case of rural households, see National Bureau of Statistics of China (2020). But these figures are averaged for all types of households. Using data from market analysts (GETChina Insights, 2019) and publicly available surveys ('Household education spending totals \$296 billion,' 2018), the authors have estimated the figure for education spending in the case of households with parents to be between 18% to 20% of their disposable income. Other estimations from education companies put this figure somewhere between 20% to 50% of disposable income (Chan, 2019).

The majority of students spend at least one hour a day on some type of additional learning, mostly online. The extracurricular burden of students caused the Ministry of Education to issue a statement in July 2019 urging schools to control the quantity of assignments during summer holidays and for parents not to arrange excessive after-school tutoring for their children. There are already regulations on extracurricular classes at schools to limit them and a proposal to ban mandatory extracurricular activities.

Teachers are also considerably better regarded in society compared to other countries. Using Shanghai as an example, and according to a 2019 OECD report (Schleicher, 2020), almost 60% of local middle school teachers felt that society attached great importance to their profession, compared with the average of 26% in OECD countries and regions. The average age of the local teachers surveyed was 39.4, which is 4.7 years younger than the average in OECD member countries. 87% of Shanghai teachers chose teaching as their first-choice career, while the average in the OECD is 67%.

With regard to technology and new methodologies, from the same report in Shanghai, 92% of teachers reported that they and their colleagues support each other in implementing new ideas compared to an OECD average of 78%. However, the promotion of independent study is lower, as only 21% of Shanghai teachers 'frequently' or 'always' ask students to do assignments that are project-oriented compared to 29% in the OECD average. In Shanghai only 24% of teachers 'frequently' or 'always' let students use ICTs for projects or class work, which is much lower than the OECD average of 53%.

1.3 Context: Economics and policy

Firstly, China is already a leading global force in the digital economy. A BCG report calculated that digital economy was already 23% of the GDP in 2017, with estimations of reaching 48% in 2035. At that time, China already had a 42% share of the global e-commerce market, processed 11 times more mobile payments than the US and is home to one third of the world's unicorns (Ruan, Tsai, Zhang & Zheng, 2017). 2020 sees the implementation of 5G mobile communications and plans to lead technical industries such as artificial intelligence, robotics or blockchain with plans such as *Made in China 2025* or *China Standards 2035*.

This digital success is fuelled by three main factors: (i) a large and young Chinese market, enabling rapid commercialisation of digital business models; (ii) a rich digital ecosystem, rapidly expanding beyond a few large companies; and (iii) strong public support – at national, regional and local levels – for companies, providing favourable economic and regulatory conditions and acting as an investor, as a consumer of digital technologies and as a provider of access to key data for companies under advantageous conditions.

Digital technologies and their implementation in the shape of solutions available for citizens are essential components of China's long-term strategy, showcasing a new wholly domestic, independent and cutting-edge industry and a technology-based approach to economics and politics. The strict application of national laws to cyberspace or the usage of AI-related technology are prominent examples differentiating China's approach.

In addition, China is shifting towards innovation – and therefore education in innovation – as an answer for increasing both the quality of products and productivity, expanding internal consumption as a means to reduce the dependence on external markets whilst adding value to its economy. Learning to innovate requires critical thinking, imagination, readiness for change, open-mindedness and a high tolerance for uncertainty. However, the existing education system may not well meet these objectives.

1.4 Objectives and structure of this study

The main aim of this study is to provide an overview of the current status of educational technologies in and around the education system in China in the hope of relevant learning for Europe. It also includes a specific examination of EdTech during the pandemic crisis. China, which was already at the forefront of educational technology before the Covid-19 breakthrough, has been the first country experiencing extensive confinement and digital schooling. Its experience can therefore be inspirational to the European Union and beyond. In the EU, since spring 2020 the Covid-19 crisis has forced an unprecedented and immediate shift to digital and online learning. The situation continues in hybrid and blended settings.

This report is structured as follows. After this background section on the education system, culture, society and the economic and policy context, Section 2 describes the methodology used. Section 3 reports on policies related to technology and the education system, while Section 4 provides some key figures of the EdTech market in China. Section 5 gathers and presents the evidence collected on the status of EdTech applications, arranged according to four typologies: in-class, beyond classes, support for the education system and advanced

education. Section 6 reviews EdTech usage and outcomes during the pandemic crisis. Finally, Section 6 is devoted to relevant conclusions for Europe.

The study is an initiative of the Human Capital and Employment Unit of the Joint Research Centre, aims at illustrating prominent educational technologies used in China and shedding some light on possible mutual learning. Since 2005, the Human Capital and Employment Unit has carried out several major studies resulting in more than 120 publications on digital age learning and skills. More information on all our studies can be found on the JRC Science hub: <https://ec.europa.eu/jrc/en/research-topic/learning-and-skills>.

Methodology

2.1 Definitions

There is no precise definition of educational technology (hereafter ‘EdTech’). Usually, EdTech is understood as the utilisation of apps and tech devices for the purpose of teaching and learning. EdTech can happen inside or outside of classrooms, at any time and in anyplace. Most modern EdTech typically involves the use of a wireless internet connection and an electronic device such as a smartphone, tablet, laptop or desktop computer.

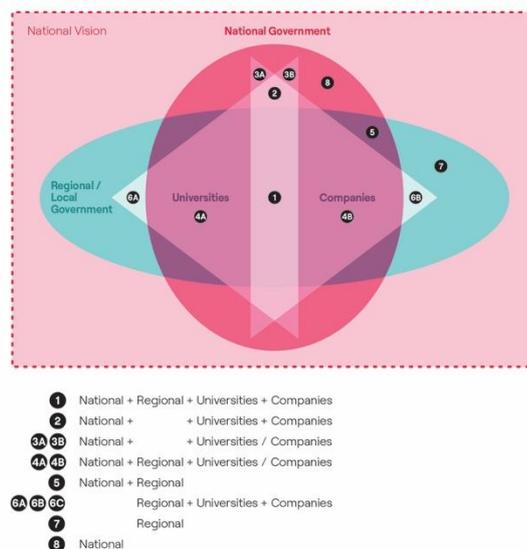
For the purpose of this document, EdTech is simply considered as the use of new technologies in and around the education system. New technologies in EdTech usually encompass AI, IoT, robotics, big data, cloud computing, blockchain and biotech. Nowadays, the most prominent within EdTech is AI, in China in particular, as the cases examined in the next section demonstrate.

AI in education primarily refers to the modelling and possible replication of human perception, cognition, reasoning and decision-taking. From a technical perspective, AI in education includes neural networks, computer vision, automated reasoning, knowledge-based systems, natural language processing, evolutionary and genetic computing and ontological, reinforcement, adversarial and machine learning.

2.2 Innovation ecosystem

The study uses the framework of the innovation ecosystem. The ecosystem is typically modelled as a structure resulting from the interaction between various innovation actors or stakeholders (Mulas, Mingos & Applebaum, 2015). The most relevant of these actors are businesses, big companies but also small companies, start-ups and entrepreneurs, financial markets, universities and research-related organisations and public institutions (Adner, 2006; Frenkel & Maital, 2014). These economic agents demonstrate economic relations but are also connected through technological, institutional, sociological and cultural interactions and emerging technologies requiring new means of governance and stakeholder participation (Kuhlmann & Ordóñez-Matamoros, 2017; Misuraca, Broster & Centeno, 2012). Within this framework, the underlying methodology is the authors’ own review of an asymmetric Triple Helix, already used to study different innovation contexts in China (Cai, 2014).

Figure 1. Government-led asymmetric Triple Helix for EdTech innovation in China



Source: adapted from Arenal et al. (2020)

It essentially consists of a government-led model that takes into account the dynamic relations between universities, industries and authorities at different levels and provides a path on how bottom-up initiatives could be integrated through the regional and local administrations with top-down plans (Arenal et al., 2020), see exhibit 1. The main objective of the top-down approach characteristic of China is a type of ‘social engineering’

aimed at achieving a 'harmonious and moderately prosperous socialist society'. This idea of 'social engineering' will be used in the remainder as an alternative to the government-led Triple Helix proposed by the authors.

In addition, innovation ecosystems are linked to some geographical space, either a suburban unit, a city, a region, a country-nation and even at supranational or global level (Thomas & Autio, 2020). The physical geography is thought to create clusters that facilitate the generation of ideas and accelerate commercialisation (Katz & Wagner, 2014). This is particularly relevant to China, since there is an increasing level of competition between regions, cities or even districts within (large) cities.

2.3 Sources of information and validation

This study uses the following sources of information: i) desk research of Chinese and foreign analyses of the education system in China and new technologies; ii) authors' direct experience of the education system in China; iii) interviews with Chinese students, parents and education professionals; iv) visits to schools and universities; v) participation in conferences on education and new technologies; and vi) authors' direct involvement in the innovation ecosystem in China.

Most of the information on the EdTech status was collected in 2019, while 2020 was used to focus on the use of EdTech during the pandemic. For the latter, a questionnaire was developed (see Annex) to interview teachers, EdTech companies and relevant Chinese institutions on secondary school and higher education through the collaboration with the Education Office of the Spanish Embassy in China. Some of the most involved centres were PKU (Beida), BFSU (Beiwai), Beijing Normal University – one of the main institutions in charge of training teachers – and the Shanghai International Studies University (SISU) and its associated high school.

The study was discussed with technology and education specialists at several events, mostly within the Global Artificial Intelligence Conference¹⁶ in Nanjing from 25-26 May 2019 and the International Conference on Artificial Intelligence and Education as part of the China Intelligence Industry Summit¹⁷ in Xi'an from 26-27 October 2019.

¹⁶ See <https://qaitc.caai.cn/en>

¹⁷ See <https://2019ciis.caai.cn>

Policies

The potential of AI and related technologies has been grasped by Chinese policymakers. As stated by President Xi, 'China ... should unswervingly follow an independent innovation path featuring Chinese characteristics, stick to the guiding principles of independent innovation, leap-frogging development in key sectors and development supported by science and technology and oriented towards the future' (Xi, 2014, p. 134).

In fact, since 2014 the executive has launched a series of key national economic initiatives that touch upon AI and its areas of development; the foremost being the 13th Five-Year Plan, the Made in China 2025 initiative, the Robotics Industry Development Plan, the Internet Plus Artificial Intelligence Three-Year Implementation Plan, the Next Generation Artificial Intelligence Development Plan, the New Infrastructure Plan and the China Standards 2035. The combined expected effect of these plans will make China the world leader in a number of key technology-based industries, such as AI, 5G, robotics or IoT in the next decades.

In any case, the framework for the development of any innovation ecosystem largely depends on policies and public bodies' initiatives. These initiatives essentially consist in measures to provide (i) favourable regulations; (ii) subsidies and financing under advantageous conditions; (iii) provide access for eligible companies to databases of personal information; and (iv) favour the implementation of tech-based applications for security, safety and other public objectives to test new solutions across the country¹⁸.

3.1 EdTech development plans

Starting with the most general plan, the 13th Five-Year Plan for National Strategic Emerging Industries aims to promote AI application in key economic and social fields. Pilot demonstrations are envisaged in manufacturing, education, environmental protection, transportation, commerce, health care, cybersecurity and social governance.

From here, the Next Generation Artificial Intelligence Development Plan (NGAIDP) outlines China's strategy to become the leading AI power in both research and deployment by 2030. It advocates incorporating AI in to many aspects of life, including medicine, law, transportation, environmental protection, and 'intelligent education'¹⁹. Following the NGAIDP's release, Chinese tech companies have secured public support and investor funding for various AI-related projects, several of which are being tested in Chinese schools in different schemes of intelligent education.

Within this framework, different levels of administration offer financial incentives to local education bureaux to encourage them to use big data and AI — incentives that typically cover the installation costs of many of the intelligent education projects.

On the international scene, online education is part of what is known as the Digital Silk Road (DSR), the digital part of the Belt and Road Initiative (BRI)²⁰, launched in 2015, that includes new technologies and aims to build a community with a shared destiny in cyberspace (Blecua & Feijóo, 2020). Fudan University's Digital Silk Road Centre divides the DSR strategy into five areas: infrastructures, such as 5G; policies, such as cybersecurity; commerce, including in particular e-commerce; finance, such as electronic payment systems; and a final area literally translated as *people's hearts*, which includes social media, videogames and online education (Fudan University Digital Belt and Road Centre, 2018).

In addition, in the international domain, President Xi declared at the UNESCO International Conference on AI and Education in May 2019 that China is willing to work with other countries to discuss issues related to AI and innovative education adaptation amid AI's rapid development: 'education transformations triggered by the rapid development of artificial intelligence have provided promising potentials to accelerate the achievement of the

¹⁸ In a speech on education from 2019, Xi argued that the purpose of education is to train for socialism with Chinese characteristics. If education ends up producing people who are ungrateful and even gravediggers of China's system, it will be 'a failure of the education system,' he said (Mai & Bishop, 2020).

¹⁹ Intelligent education refers to the usage of AI in and around the education system.

²⁰ The Belt and Road Initiative (BRI), a general framework of international cooperation that President Xi presented at the beginning of his mandate in 2013. The name chosen for this economic corridor connecting China to Europe has strong historical connotations and refers to the Golden Age when China was at the centre of world trade. The BRI basically runs inland through Central Asia, via the maritime route across the Malacca Straits, or, combining land and sea communications, from Pakistan. Previously known as One Belt One Road (OBOR), the most popular name internationally since 2015 has been the BRI, although the Chinese name has remained unchanged. The initial objectives focused on promoting connectivity and coordinating development initiatives across the Eurasian countries, although lately include Africa, Latin America and even the Arctic. As is often the case with Chinese policies, while the long-term strategic goals are clear, its practical definition and implementation is rather lax and flexible, and both its geographic scope and content has evolved in line with Chinese interests (Blecua & Feijóo, 2020).

SDG 4 Education 2030 Agenda, and to enhance our confidence in reaching consensus and deepening cooperation’ (‘Working towards an international community on AI in education’, 2019). During this conference, China also expressed its interest in ensuring inclusion and equity in education amidst widespread digitalisation. The Director of the UNESCO Beijing office, Marielza Oliveira, said ‘It is impressive how fast China created partnerships between national and local administrations, private sector and civil society, so that these capabilities could be augmented by additional learning resources through, for example, TV broadcasting and social media live streaming’ (Halsall, 2020).

3.2 Public EdTech-related projects

China is building, as of 2019, 100 state-level virtual reality education centres for teaching scientific knowledge and skills. This is part of the plan issued in April 2018 by the Ministry of Education on the AI Innovation Action Plan for Colleges and Universities.²¹ It proposes establishing one hundred AI and other advanced topics complex specialties, publishing fifty world-class teaching materials for undergraduate and graduate studies, developing fifty national-level high-quality online open courses, as well as establishing fifty artificial intelligence faculties, research institutions or interdisciplinary research centres by the year 2020. It also plans to train more than 5,000 students and 500 teachers from top universities in AI within five years.

The plan also suggests introducing education for AI at primary and secondary school level. To this regard, Guangzhou will begin offering courses on AI to primary and middle school students from September 2019. The pilot (see next section on experimentation in policies in China) will cover 100 schools. By 2022, all primary and middle schools in the city will have AI courses in their regular curriculum.

There is also a National Engineering Laboratory of Virtual Reality (VR) / Augmented Reality (AR) Technology and Application that seeks to support the R&D and engineering of content capture, data modelling, sensors, haptic feedback, new displays, image processing, surround sound, ultrahigh performance processing terminals and VR/AR testing. It is primarily aimed at areas such as live sport broadcasting, defence and education. This laboratory is currently in the Laoshan district in Qingdao, Shandong, led by Beihang University, although it also has a branch at Beijing University of Technology (BIT).

In addition, by the end of 2020, China plans to build 10 demonstration zones to showcase the innovation and best practices of AI-integrated education services.

3.3 Educational policies and reforms

China’s government typically conducts many different experiments on new policies and developments at local level that, if satisfactory, are extended across the country. The administration essentially allows the experimentation of new technologies and business models from private and public companies and, only when there is some degree of success, is the new situation then checked to be aligned with societal objectives, further supported and extended to other areas.

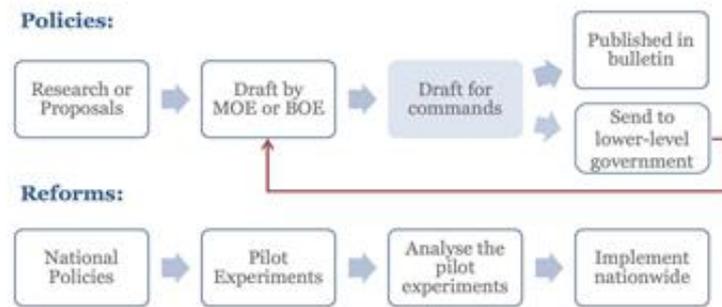
In fact, there are many initiatives taking place in China at regional and local level supported by the respective authorities. China has 17 national-level innovation demonstration zones, which have been selected by the State Council and enjoy favourable policies to encourage innovation and regional economic growth. This creates a particular type of competition between different locations – or clusters of locations, or even districts within a large city – that is a main feature of China’s innovation ecosystem.

In the case of educational reform, there are long-term goals, such as 2035, but in practice the plans and projects are refined and reviewed every two to three years.

Figure 2. Educational policies and reforms in China. Source: OECD (2016)

²¹ http://www.moe.gov.cn/srcsite/A16/s7062/201804/t20180410_332722.html

Educational Policies and Reforms



Since July 2017, the State Council and local administrations in many provinces have issued a number of policies encouraging non-exam-oriented, innovative and practical education. In December 2017, the Minister for Education released the “Curriculum plan of general High school and curriculum criterion of subjects like Chinese Language (2017)” (known as the ‘new curriculum criterion’) and formally included content on artificial intelligence, STEAM and ‘maker education’. The new curriculum emphasised the diversity of courses and student choices in order to promote personalised education for all. On the one hand, the new curriculum placed great weight on traditional Chinese cultural education. On the other hand, it added robot design & making, STEAM technology & liberal studies, data management & analysis and artificial intelligence subjects into the general technology and information technology curriculum.

Figure 3. Technology curriculum in China. Source: MoE (2016)

High school general technology curriculum structure

	Required courses		Optional required courses	Optional courses
Modules	Tech and design I	Tech and design II	Tech and life; Tech and engineering; Tech and career; Tech and creations	Traditional crafts and practice; New tech experience and exploration; Tech integration and application; Modern agriculture tech

High school information technology curriculum structure

Categories	Modules	
Required courses	Module 1: data and calculation Module 2: information system and society	
Optional required courses	Module 1: Data and data structure Module 2: Internet basics Module 3: Data management & analysis	Module 4: Preliminary AI Module 5: Three-dimensional design & creation Module 6: Open source project design
Optional courses	Module 1: Preliminary Algorithm Module 2: Mobile application design	

In February 2019, the Ministry of Education officially issued an educational development plan entitled *China's education modernisation plan 2035*. It is planned to be developed over the course of three years and intended to serve as the framework for China's education reform and development. The plan's main aim is to improve the quality of education across the country and enhance its innovative capacity.

In a next step, on 9 July 2019 the CPC issued a guideline for advancing education reform and improving the quality of compulsory education (‘Opinions on Deepening Education and Teaching Reform to Improve the Quality of Compulsory Education’ (关于深化教育教学改革全面提高义务教育质量的意见)). It is the first such guideline since the founding of the People's Republic of China in 1949 and it primarily refers to the first mandatory nine years of schooling: six years for primary education and three for secondary.

A main aim of the document is to stop the evaluation of middle schools based on the how many of their students go on to enrol at good high schools. Instead, it proposes the evaluation of the quality of teachers – foreign teachers in particular – and public opinions on their performance. The objective is to improve the quality of classroom teaching so students do not need to work in excess after classes.²²

Nevertheless, most of the schools in China are based on legacy content. However, this reform brings the system in the direction of the European reforms at the end of the 20th century, to develop an education curriculum based on competences. STEAM education together with new technology education – such as software and robotics – are the fields of experimentation to introduce cooperative teamwork and project-based learning into the Chinese system.

Online education is less restrictive in the case of adult education compared to compulsory education. Degree education in China is rather restricted and subject to a long process of approval, but other areas such as remote degree education, Massive Open Online Courses (MOOCs), online lifelong learning and online foreign language learning are comparatively more open (Australian Trade and Investment Commission, 2018).

Finally, during July 2020, new legislation on foreign language teachers was passed. In a nutshell, the key parts of the legislation imply that foreign teachers will be governed by the same credit system and expectations as their nationals. This implies control over the curriculum and also the creation of a special register for foreign teachers, linked to the council statistics and special training of at least 20 sessions on ‘Chinese particularities’²³.

3.4 Talent cultivation

A key aspect of education with new technologies is the availability and cultivation of talent. The number of experts in new technologies is considered insufficient in China, and in 2018 alone, the Ministry of Education gave permission to 35 universities to launch new degrees related to AI. Similarly, in 2018 Tsinghua University published a report that estimated the talent deficit in the big data domain to be around two million people in 2025 (Yunhe et al., 2018).

For these reasons, China has launched a special programme to identify, capture and promote talent in secondary education. It is a global programme, not just for China, and its aim is the development of young entrepreneurs. The program provides all-round support from the perspective of continuing learning, starting a business and project incubation and focuses on cutting-edge technology, AI in particular.

The programme started in the summer of 2020 with three activities: the Global Youth Turing Selection Campaign, Global Youth Turing Program Training Camp and the Global Youth Creativity Summit. Students will be selected from the best projects in the first three-month activity. If successful, the programme will be repeated and escalated in subsequent years.

3.5 Online education regulation

There is a growing interest in the use of technologies, including big data and artificial intelligence, in the regulation of online training institutions, as well as in establishing technical standards for online education and setting up independent, transparent and reliable evaluation systems for the institutions, all of them pending tasks in the Chinese education system.

In fact, as a continuation of the document mentioned in the section above, on 15 July 2019, another guideline document was issued on ‘Implementation Opinions on Standardising After-School Online Training’ (关于规范校外线上培训的实施意见). It regulates, for the first time, the activity of online companies beyond classes. The guideline was issued by six central administration departments, including the Ministry of Education, the Cyberspace Administration of China, the Ministry of Public Security and the National Office Against Pornographic and Illegal Publications. Consequently, the vast majority of online training organisations will be under official supervision with the main goal of reducing the after-school burden on students.

The guidelines require all online training organisations to register with provincial educational administrators with information including appropriate licenses, training content and training staff. Those teaching academic courses must have appropriate teaching qualifications. The organisations need to display names, photos and

²² Assigning homework to parents is also a common practice that the guidelines aim to stop.

²³ China’s MOE explained the main reason for new legislation relates to the number of unqualified teachers – specially for English language teaching – and the need to raise the bar at their level. However, there had been official answers and comments from EU and other institutions, as the individuals and the international schools and institutions may be affected and supervised in ways that could be considered unacceptable. A summary of the regulation is available at LegalTips (2020).

qualifications of teachers on the training platforms and the pages of the courses they teach. If the teachers are foreigners, the information should also include their study and work experience. Hiring teachers already teaching at primary and middle schools is illegal. The guidelines require the agencies to teach content suitable for children without obscene, violent, horrible, gambling content or games.

In addition, the courses offered must match students' cognitive ability. Teaching students content beyond the national syllabus or above the grades they are in is disallowed. All training content data should be stored for at least one year and videos of teaching should be saved for at least six months. The guidelines also note that the training time should be designed according to students' ages. Each class is required to be no more than 40 minutes and breaks should be at least 10 minutes. Live teaching should not be offered during school time and training classes for those in Grades 1 and 2 should be designed without homework. Live classes for primary and middle school students should be conducted before 9 p.m. All online training platforms should be provided with functions to protect eyes and enable monitoring by parents. The organisations also have to prominently display charges and refund information. They are required to charge fees for no more than 60 classes in three months, providing fair contracts that do not infringe upon consumers' rights while mitigating or exempting the responsibility of training operators.

Finally, the guidelines ask all provincial educational administrators to finish inspecting local online training organisations by the end of 2019 to make sure they are registered and meet standards. Those with problems should finish rectification and re-registration by the end of June 2020. If they fail to rectify problems, they face fines and closure. The guidelines also call for the establishment of a national supervision platform.

3.6 Code of conduct for teachers

No review of the policies relevant to the education system in China and the EdTech domain would be complete without mentioning the code of conduct for 'College and University Teachers in the New Era' (Ministry of Education of the People's Republic of China, 2018). The annex uses a transcription of the key principles. The first and foremost refers to a political stance upholding the leadership of the CPC

3.7 Ethics & privacy

As of 2019, China²⁴ has released what are known as the Beijing AI principles (Beijing Academy of Artificial Intelligence, 2019), a code of ethics in AI, similar to other ethical frameworks launched in the EU²⁵. Although their possible impact in areas such as privacy or individual freedoms is still unclear – concepts usually interpreted in China in dissimilar ways to western countries – and the distance from regulation to implementation is also well known in China, it is a sign of willingness to discuss the ethics of AI. Different to other codes, society's well-being is given pre-eminence compared to individual rights.

During September 2020, the same organisation released a document on 'Artificial Intelligence for Children' (BAAI, 2020) that states that the development of AI should protect and promote the benefits of children, avoid depriving and harming children's rights and help realise the healthy growth of children. Values for children mentioned in the document are dignity, free development and the diversified growth of children, non-discrimination and an overall priority to benefit children. Specific children's rights that should be protected, according to the document, are physical and mental safety and health; privacy, legal, proper and necessary collection of data; more inclusive, fairer, and quality education for children; and free expression of their opinions and wishes. The document calls for taking responsibility in the domain of AI for children including developers' ethics, minimising risks, providing transparency and interpretability, developing policies and ethical norms and improving the existing legal system. It ends with a call for a 'cross-regional, global, and comprehensive AI governance open cooperation platform [...] to share governance experience and methods of AI for children, to promote the common development of global governance of AI for children, and to empower the healthy development of children all over the world in the era of AI.'

With regard to EdTech, it is still too early to acknowledge any impact in the existing developments, and during the research for this report there was no direct discovery beyond the reluctance to use these technologies in schools expressed by some teachers, parents and students. In the European Union, a general concern regarding the ethics of AI in the field of education has led the European Commission to propose in the Digital Education

²⁴ The code was developed, among others, with Peking University, Tsinghua University, the Chinese Academy of Sciences, Baidu, Alibaba, and Tencent. Although it has no explicit official support, analysts interpret it as an initial experiment in the direction of AI and ethics in China.

²⁵ See, for instance, the European Ethics Guidelines for Trustworthy Artificial Intelligence: <https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai>

Action Plan (2021-2027) a line of research to develop ethical guidelines on artificial intelligence (AI) and data usage in teaching and learning for educators, and to support Horizon Europe research and innovation in this area.²⁶

The privacy of children, in relation to the education system, is also starting to become an issue in China. The generation born around 2010 has now started to realise that their lives have been exposed in publicly shared social networks, in a phenomenon called 'over-sharenting'. As in many other regions in the world, surveys in 2019 show that parents of up to 80% of children from Grades 3 to 5 had been sharing photos and assignments online without their consent and had compared their children with others. The public and children have started to notice the consequences in the form of increased stress and security risks.²⁷

²⁶ https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan_en

²⁷ The expert Michelle Wolfe estimates that, by the time a student reaches 16 years of age, 'there can be a million points of data or more on a student. That paints a very comprehensive picture that can be used, or misused, by many different individuals and organizations' (Franklin, 2020).

EdTech market in China

China's online learners reached 172 million in 2018, among which 142 million are learning via mobile devices, with growth rates of 10.7% and 19.6% respectively. The online education market was valued at USD 37 billion in 2019 and was expected to reach USD 56 billion in 2020, with an estimated 20% growth in subsequent years (Chan, 2019). China's Online K-12 Education Report in 2018 indicated that the annual expenditure for online K-12 education per capita was RMB 6,000.

In 2018, the total investment in EdTech in China reached about EUR 4 billion, which is almost double the 2017 total. 417 companies were given investments – 56% higher than in 2017. The two largest sub-sectors in EdTech in China are K-12 education and language learning (see Figure 4), amounting to 80% of the top 10 investment deals in 2018 so far. However, the STEM education sector is the fastest-growing sector – three times more cases were funded than in 2017.

China is expected to surpass the US in the EdTech field in subsequent years. According to HoloniQ (2020), in 2020 the US and China both share the leadership position for the EdTech landscape. Both host 8 unicorns in a shortlist of 18. The capital flow into EdTech in China more than doubled that of the US since 2010 (USD 198 billion from China vs the US's USD 9 billion) (Fannin, 2020).

As of June 2020, the eight unicorns in EdTech in China are: Yuanfudao (also known as Yuantiku), 17zuoye, VIPKid, DaDaABC, Makeblock, CCTalk, Changing Edu and Huikedu ('8 China's EdTech start-ups leading the global educational technology market' (2020)).

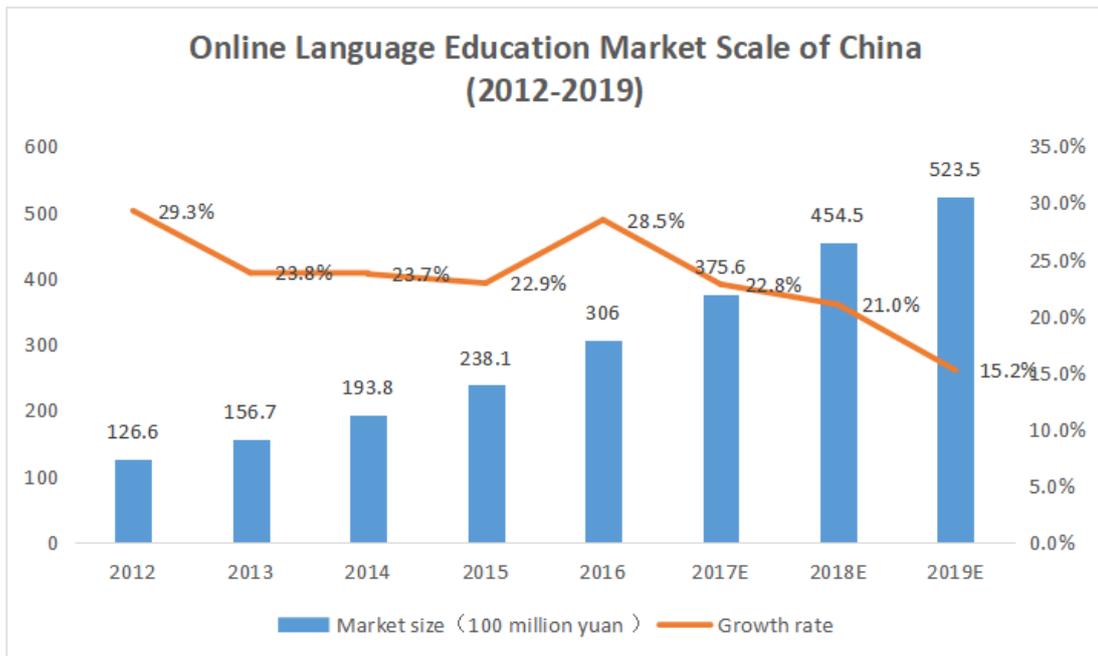
The proportion of early-stage venture capital investments and later rounds are roughly similar in 2017 and 2018, indicating that the structure of the EdTech market as a whole is relatively steady. However, big companies in the industry who have education or ed/culture-related businesses have been strategically investing in startups and seeking synergistic cooperation. This has made the market more integrated. Zuoyebang stands out on the list by raising 2 rounds in 3 months with a total of USD 850 million, replacing VIPkid as the most funded EdTech company (see section below for a description of projects and companies).

Most of the EdTech companies primarily grew their business in the largest, tier 1 cities, but have faster growth in smaller tier 3 and 4 cities.²⁸ The greater demand in China's smaller cities is due to a lack of institutions and teachers of the same quality available in the main tier 1 cities (Chan, 2019).

In a typical situation, parents will pay RMB 300 for a 25-minute online native English teacher class for their children. On the other end of the spectrum, a 1-on-4 class English lesson with live streaming Filipino tutors only costs RMB 100 per hour.

²⁸ The classification of cities in tiers is the most usual form of distinguishing between cities in China. It is not an official classification, but it is widely used by market analysts and experts. Tier 1 has traditionally composed of Beijing, Shanghai, Shenzhen and Guangzhou. Some experts add Tianjin and Chongqing to this list. In 2018 the financial magazine Yicai Global decided to update the list to also include Chengdu, Hangzhou, Wuhan, Nanjing, Suzhou, Xi'an, Changsha, Shenyang, Qingdao, Zhengzhou, Dalian, Dongguan and Ningbo ('2017'新一线城市排行榜发布成都、杭州、武汉蝉联三甲郑州、东莞新晋入榜' (2017)). A general explanation on the tier classification can be found in China's cities classification ('China's cities classification' (2016)).

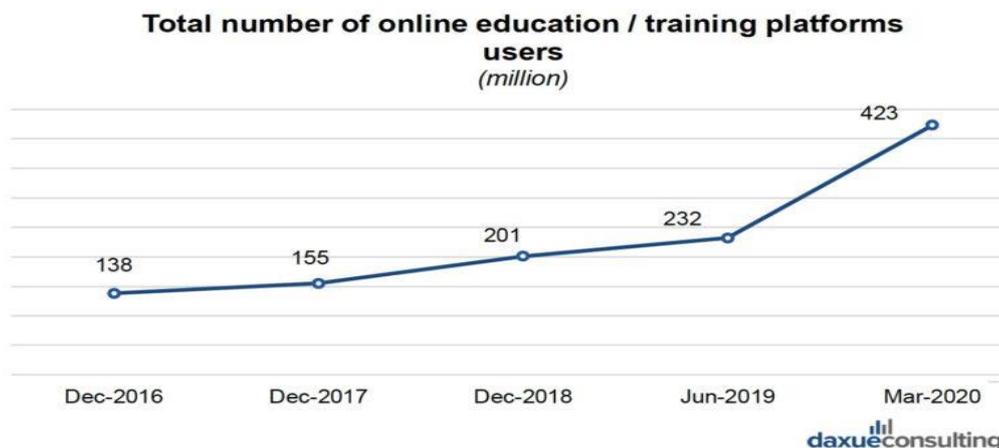
Figure 4. Evolution of the online education market in China



Source: Online English Education Industry Report (‘艾媒：2017 上半年中国 K-12 在线英语培训行业专题研究报告’ (Ai Media: Research report on the online English education K-12 industry in China 2017))

The effect of the pandemic on the EdTech market has been considerable. The confinement policies have represented a large-scale catalyst, leading to more of a need for online education business and users. China's Statistical Report on Internet Development mentions that the country reached 423 million online education users in March 2020, which represented an increase of 110% year-on-year, see figure 5.

Figure 5. Total number of online education users in China



Source: (‘2020 年在线教育报告出炉！三方资本围猎，下半场靠什么狂欢？ (2020 Report on online education)’ (2020))

Analysis of EdTech projects

The EdTech applications currently in place in China can be divided into (i) advanced education, typically for STEM education; (ii) in-class; (iii) additional education beyond regular classes; and (iv) support for the education system.

5.1 Advanced education

China is going through a process of transformation for primary and secondary education related to technology. It follows the usual approach of conducting experiments in schools, evaluating their results under the lenses of technological progress, societal harmony and socialism with Chinese characteristics and, if successful, scaling them up to other schools.

In the private sector, an increasing number of startups aim at providing young students with advanced education in programming (visual programming for younger children), robotics, artificial intelligence and the Internet of Things.

There are also proposals to use new technologies such as VR and 5G in the education process with the aim of providing interactive education. In the case of China, developing and rural regions still struggle for quality education and it is expected that the combination of 5G and interactive education, and EdTech in general, will help to reduce the gap (Abbey et al., 2019).

In addition to the experiences summarised below, startups in this sub-sector typically opt for three different major business models: (i) tools, (ii) offline and online courses and (iii) platforms. In the case of tools, the companies develop hardware and software that are more friendly for students. Courses and tutoring can be online or offline and can include pre-recorded or live stream videos, one-on-one or one-on-several tutoring class settings. Platforms typically combine online learning communities, gamified lessons and students' assignments.

High School Affiliated to Renmin University (RDFZ)

This is generally acknowledged as the best school in Beijing and one of the elite schools in China. It is the number one for AI educational programmes and also where main experiments take place with new programmes, to be later extended to other schools if successful. The school provides the Chinese education curriculum, and it is a top achiever at *gaokao* and also provides the International Baccalaureate (IB) and the Advance Placement in English for students wishing to study abroad.

The school provides about 200 elective courses and the students should select at least six. Technology areas cover, for instance, robotics, drones, artificial intelligence, satellite systems and space exploration and programming.

For example, the computer science curriculum for high school students approved by the Ministry of Education consists in two compulsory courses on 'Data and computing' and 'Information systems and society', and then six more selective courses on 'Data and data structure', 'Foundation of networks', 'Data management and analysis', 'Preliminary artificial intelligence', '3D design and creativity' and 'Open source hardware project design', and finally two elective courses on 'Introduction to algorithms' and 'Mobile application design'. In fact, the school has already participated in the elaboration of the new textbooks supporting this curriculum on computer science and AI – issued in 2019 – and works on the textbooks for computer science and AI primary education to be published in 2020.

During the 2018-19 school year, the school provided the following courses on AI. Two compulsory: 'Data and computing: Introduction to AI' and 'Preliminary artificial intelligence', and then several elective: 'Modelling and simulation', 'Data mining', 'Autonomous driving', 'Artificial intelligence and the biology of the mind', 'Machine learning: The core algorithms of AI', 'Natural language understanding and social humanistic computing', 'Natural language processing', 'Computational sociology', 'Robots and AI', 'Computational vision and deep learning', 'Brain-computer interaction'.

To be able to implement this programme, the school uses expert advice and the support from top universities and research institutions including key laboratories²⁹ in universities in Beijing, most of them located in Zhongguangcun, known as the Silicon Valley of China.

²⁹ There are key laboratories at national and regional level that get direct funding from the respective governments.

Content is based on approved texts and material from platforms such as Coursera³⁰ and other MOOCs. They also use hardware from companies such as Lego, JDI and others. Key material is either donated or provided by companies for free.

Work carried out by students is project-based. The work is also motivated by competitions such as programming Olympics and NASA and International Space Station contests. Gifted students are selected and recommended for key courses. They also do internships in startups, mostly after graduation. They are also encouraged to act as assistant professors on these courses. Students have the courses placed within the standard framework of classes and then they can stay to use the facilities after classes. There is a male-female gap in attendance at technology classes that tends to disappear if technology is combined with social sciences.

The evaluation of the performance of courses is decided by the top leadership of the school while the proposal of new elective courses comes from the group of professors in a particular area. If the courses and the education are successful, the professors explain the methodology and provide materials at meetings with other schools (typically of about 100 attendants) promoted by a CPC branch in charge of education. To extend this approach, the professors and the principals are also sent to other schools temporarily, videoconferencing facilities are also used and this school in particular sends some professors to remote regions for up to two or three years, receiving some professors from there also.

In the case of AI, the group of five professors are rather young (about 30 years), including PhD and master's degrees from the best universities in China, some with experience abroad (primarily in the US). The group is female-led. It is perceived that women tend to think education jobs provide a better life balance with their offspring. The professors stay connected to their universities' former supervisors and go to technical conferences when possible. This group of professors was sceptical of the implementation of in-class AI technologies such as the ones explained in the next section.

University education

In the area of universities and research institutions, there is an annual ranking based on (i) AI academic performance, essentially publications in journals; (ii) the influence the university has in the AI domain by means of positions of alumni in firms and the university's reputation; (iii) the performance of those specialising in AI, who usually go to universities devoted to computer science and mathematics; and (iv) a comprehensive university performance not exclusive of AI. As of 2018, the top ten universities were Tsinghua University, Peking University, Zhejiang University, Shanghai Jiaotong University, Nanjing University, Fudan University, the Harbin Institute of Technology, the University of Science and Technology of China, Huazhong University of Science and Technology and Southeast University.

In general, AI teaching and research was previously carried out through the cooperation of the faculties/schools of the related specialisms, such as computer science, mathematics and electronic engineering. Recently, with the rapid development of AI and the support of policies, specialised graduate and postgraduate schools of artificial intelligence have been founded in all the main universities in China.

Tsinghua University owns the State Key Laboratory of Intelligent Technology and Systems³¹ belonging to the school of computer science, which provides teaching and research in AI. The students have the chance to work in the laboratory or related research organisations from the second semester of the first year of university and usually publish their results in the top AI conferences and/or journals.

In the case of Peking University, the Department of Machine Intelligence – formerly the Center for Information Science³² – was established through the cooperation of ten departments, including mathematics, computer science and electronic engineering. It is primarily dedicated to the interdisciplinary research and teaching of machine perception, intelligent information processing and machine learning.

In Shanghai Jiaotong University, the intelligent voice technology research of the computer science department has won many international competitions, which has provided for a good reputation at international level. As a technology-focused university it is involved in the industrialisation of technology. In particular, the success of Aispeech Inc.³³, a spin-off company from the university at the Suzhou Industrial Park, has become a landmark. This is a speech technology provider which focuses on end-to-end spoken dialogue system technology and specialises in providing innovations for intelligent hardware, such as in-car devices, smart homes and robots. It was first founded in Cambridge, UK, in 2007 and moved back to Suzhou Industrial Park, China, in 2008. In

³⁰ <https://www.coursera.org>

³¹ <http://www.csai.tsinghua.edu.cn/>

³² <http://www.cis.pku.edu.cn/>

³³ <http://www.aispeech.com/>

January 2018, the school of artificial intelligence was founded, which will carry out the research based on 'Data, Algorithm and Chips' with a focus on the fundamental theory and technology, chips and system architecture and its applications such as smart cars.

The University of Science and Technology of China in Hefei (Anhui) has a considerable reputation in the fields of industrial automation, intelligent equipment control, pattern recognition and intelligent information processing, etc. The voice technology company iFlytek was launched by alumni of the university. The university and the company have together founded a national key laboratory, named the 'National Engineering Laboratory for Speech and Language Information Processing (NEL-SLIP)' in which Fudan University, Shenyang Institute of Automation of the Chinese Academy of Sciences, the Institute of Microelectronics of the Chinese Academy of Sciences, the Institute of Neuroscience of the Chinese Academy of Sciences, Baidu Inc. and Microsoft Research Asia are also involved.³⁴

In March 2018, Nanjing University (NJU) announced the establishment of the Artificial Intelligence School³⁵. At the same time, JD.com – the second e-commerce company in China after Alibaba – announced the Nanjing branch of the JD Artificial Intelligence Research Institute, which will be built near the NJU and will become the training station for the students at its Institute of Artificial Intelligence³⁶. In addition, in April 2018, the Nanjing Turing Artificial Intelligence Research Institute was founded, which is led by Yao Qizhi, winner of a Turing Award³⁷.

There is also a National Engineering Laboratory of Deep Learning Technology and Application led by and located in Baidu Inc³⁸. The organisations that cooperate in this laboratory are Tsinghua University, Beihang University, China Electronics Standardization Institute and the China Academy of Information and Communications Technology.

Selected cases

Table 1 below summarises main cases of advanced education. They have been selected because of their relevance and/or popularity in China as described in the table.

Table 1. Summary of advanced education cases

Case	Description	Remarks
DJI	In 2019 it launched its first-ever robot built explicitly for education –the <i>RoboMaster S1</i> . The <i>S1</i> is a full robot system with configurable components and AI programming.	The world's leading company in drones for aerial photography and videography.
Hetao Coding Code Mao	Recorded courses for learning to code. Live streaming courses for learning to code.	Free courses during the pandemic.
Hulkedu	Online courses and R&D labs on topics such as AI and robotics, primarily for higher education institutions.	Startup with unicorn status.
Makeblock	Robotics company that helps primary school children learn basic coding using Scratch with its fee software, mBlock.	According to the company, more than 70% of income comes from overseas markets with over 8 million users worldwide, in over 140 countries. During the pandemic, <i>Makeblock</i> launched their 'at-home resources' in March to adapt to online education with the pandemic.

³⁴ http://www.xinhuanet.com/politics/2017-05/13/c_1120967231.htm

³⁵ <https://medium.com/@pandaaily/nanjing-university-announces-new-artificial-intelligence-school-9a23777e72a>

³⁶ https://www.nju.edu.cn/_t465/f7/d4/c3814a260052/pa geh tm

³⁷ https://www.jqknews.com/news/8046-Academician_Yao_Qizhi_72_started_his_first_venture_and_set_up_Nanjing_Turing_AI_Research_Institute.html

³⁸ <https://www.dlne.org/>

NetDragon	This has developed a virtual reality lab for physical and chemical experiments including a digital board for schools.	Partnership with China Mobile to use 5G and make developments available in schools nationwide.
TokyLabs	This uses its own hardware to build an IoT ecosystem based on WiFi and Bluetooth.	Spanish startup being developed in China due to market potential.

Source: own research.

5.2 In-class

Current EdTech being trialled in class includes video cameras, drones and brain headsets to ascertain students' level of attention, help them to focus and provide this information to the professor in real time and, in some cases, to parents through mobile applications. The same types of technologies are used to gain a deeper understanding of the students' learning process and provide support as needed. These technologies rely on deep learning for image and pattern recognition and classification. Systems can provide in-class behaviours, which are divided into categories, reading, writing, listening, standing up, raising hands and lying on the desk; identify different facial expressions: neutral, happy, sad, disappointed, angry, scared and surprised; and guess the status and motivation in the learning process. The data is used to generate an indication of a student's performance and particular recommendations to improve the learning outcome. Some applications being tested can also read students' notebooks.

Teachers and experts question the extent to which mere facial and pattern recognition systems can improve student performance. Experts say there are many technological, legal and moral barriers to overcome before this type of recognition can be widely deployed in Chinese education.

Selected cases

Table 2 below summarises the main cases of in-class education. They have been selected because of their relevance and/or popularity in China as described in the table.

Table 2. Summary of in-class education cases

Case	Description	Remarks
Alo7	<p>This is a K-12 EdTech company focused on teaching English.</p> <p>The company offers products and services for both physical and digital classrooms.</p> <p>It has an online learning platform, paired with a collection of textbooks that help students learn and practice their language skills. It also has a service that connects with English tutors abroad via video for regular group lessons.</p> <p>The classroom is used for the part of the learning requiring creativity, like writing and conversation. The process is supported by algorithms that measure how much time the students spoke English in class, the accuracy of their English pronunciation and basic indicators of their engagement and joy, such as the number of times they opened their mouth to speak and laugh.</p>	<p>According to the company, as of 2020, it has served some 15 million students and teachers and partnered with 1,500 institutions nationally.</p> <p>In 2019, the company created several physical classrooms equipped with cameras and microphones to showcase its analysis.</p> <p>Teachers also get reports on their own performance.</p>
BrainCo	<p>This is dedicated to developing brain interface technologies to detect and quantify students' attention levels based on built-in EEG scanners. The headbands come with a portal that the company presents as 'the world's first classroom portal for teachers to assess the effectiveness of</p>	<p>Harvard University-originated startup based in Boston and founded by two Chinese students.</p> <p>The company said in January 2019 that it had already tried this band on 10,000 Chinese students aged between 17 and 21 for three weeks.</p>

Case	Description	Remarks
	<p>their teaching methods in real time and make adjustments accordingly' (Feng, 2019).</p> <p>The latest release of its technology is aimed at helping students to focus and increase concentration during learning.</p>	
Pearson	<p>Pearson, the UK-based educational group, provides education for the vocational training sector in China.</p> <p>It has localised content from the Business and Technology Education Council for the needs of employers in China using online mobile technologies.</p>	<p>Courses aim to provide new opportunities not only in China but in the BRI countries.</p> <p>This is part of an agreement between the Ministry of Education of China and centres in the UK to establish a Belt and Road programme to cooperate in skills education between the two countries.</p>
Responsive4U	<p>This is a project, started in 2018, to allow students to take for-credit university courses via a combination of online and in-person classes.</p> <p>It uses pre-recorded sessions and a 'compressed mode of teaching', where didactic learning could be limited to three or four intensive weeks of online instruction, leaving additional time for exchanges, experiential learning or service in the community. The final objective is HyFlex, or hybrid-flexible, models, in which each class would have both online and face-to-face versions, which would run in parallel.</p> <p>During the project, it was found out that these initiatives were more demanding on lecturers and required additional resources and teacher training.</p>	<p>The participating institutions – the University of Hong Kong (HKU), The Hong Kong University of Science and Technology, Chinese University of Hong Kong and Hong Kong Polytechnic University (PolyU) – had to work together to find solutions for technological, scheduling and other logistics hurdles.</p> <p>In 2019, the project had 11 courses taken by 2,000 students.</p> <p>The project has been upgraded and used as a basis for the response to the pandemic crisis during 2020.</p>

Source: own research

5.3 Beyond classes

One special feature of China's education market are the generalised after-school institutions. After-school institutions are organisations that are separate to a student's regular school that provide supplementary education to students of all ages. They are a place where students can gain a holistic education, receive tutoring, do test preparation, learn languages, participate in extracurricular activities and even gain vocational education skills. The size of the K-12 after-school market was estimated to be about EUR 60 billion in 2018. In 2016, there were more than 200,000 after-school institutions across China.

Because of China's education system, more than half of the students will choose to take after-school tutoring classes, especially before taking the university entrance exam. It is estimated that in 2017, China's urban students spent around 10.6 hours each week on various after-school classes. The pressure of exams and high-performance expectations are the main reasons parents register their children for classes. High school student participation reached 58%. About 50% of the after-school institutions are geared towards K-12 education and focus on tutoring for academic subjects. Sectors specialising in vocational education (professional certificates), holistic education (competence-based education) and language learning are also growing markedly.

Existing applications in the beyond classes segment tend to become online for two main reasons: the increasing chances of scaling up, and the prices of renting a location in tier 1 and tier 2 cities in China.

Therefore, EdTech beyond classes is an extension, a complement and/or an alternative to these after-school institutions and is primarily based on apps and distance-learning applications to improve students' knowledge

of English and maths, in particular. AI is used to provide a tailored approach to each student and convert text-to-speech and vice versa. Some of the startups in this field in China have already acquired unicorn status.

However, as detailed in the section on policies, on July 2019 China's Ministry of Education announced new rules for online education companies to increase control of the after-school tutoring industry. Costs are usually around Chinese RMB 2,000 to 3,000 per month, which is at least RMB 20,000 to 30,000 per year for English alone. Note also that online institutions are often engaged in exam-oriented training that has increased workloads for students. China will carry out a comprehensive inspection on all online after-school training institutions and keep a record of the institutions, their training content and teacher credentials by the end of this year as part of its oversight of the rapidly expanding industry.

Selected cases

Table 3 below summarises the main cases of education beyond classes. They have been selected because of their relevance and / or popularity in China as described in the table.

Table 3. Summary of education cases beyond classes

Case	Description	Remarks
17zuoye	<p><i>17zuoye</i> (一起作业, a word play with the Chinese for 'homework together') focuses on providing services and products – homework, assessment – for primary mathematics and English learning for K-12 students with support for teachers and parents.</p> <p>The platform aims to improve learning efficiency and efficacy and convert student homework from offline to online. Their mission, as stated on their website, is 'utilising advanced education technology, quality educational content, and continuous educational enthusiasm' in order to 'provide more efficient and beautiful products and experiences for K-12 stage schools, families and social education scenes, opening a new era of intelligent education.'</p>	<p>Its total disclosed funding has reached USD 335 million and already has a USD 1 billion valuation.</p> <p>As of June 2020, it is the largest online educational platform in China.</p> <p>Figures from February 2018 disclosed by the startup mention that 17zuoye has served over 60 million users and 120,000 schools by offering homework applications to instructors, students, and parents.</p>
Bilibili	<p><i>Bilibili</i> –Nasdaq listed – has found a separate niche based on synchronised online interactions.</p> <p>The key feature of the platform is its danmu (bullet comment system) where time-synced comments are overlaid directly on top of the video as it plays. The comments can either be in real-time or left by previous viewers pegged to specific moments of a video. This type of interaction creates a social watching experience similar to that of sitting in a real-life event.</p> <p>Another key factor is that there is a high threshold for membership and to be able to upload videos or prioritise comments in particular.</p>	<p>Short videos on mobile handsets are a thriving market in China, with well-known applications such as Douyin (from Bytedance) or Kuaishou (from Tencent).</p> <p>The company started in 2009 as an online site for animation, comics and games, and in 2020 its 100 million monthly active users spend on average 81 minutes on the site per day, playing videos for a total of 510 million times. The platform has 89% original content thanks to 730,000 content curators.</p> <p>Consequently, the Bilibili platform has become China's top self-learning platform, with 4.2 million videos on a variety of educational topics accessed by 19 million learners per day.</p>
Changing Edu	<p><i>Changing Edu</i> is an O2O (online to offline) educational service connecting students, parents and teachers to facilitate after-school learning services. Parents can post enquiries regarding tutoring services, and the mobile service app helps connect tutors to students. The company uses an online</p>	<p>As of 2020, the platform currently operates in 11 cities, including the larger cities of Shanghai, Beijing, Shenzhen and Wuhan.</p> <p>During the pandemic, the startup provided a free online teaching platform for self-employed teachers and smaller educational institutions in the industry.</p>

Case	Description	Remarks
	platform to make offline matches for one-on-one, at-home tutoring services.	
DaDaABC	The most interesting aspect is that the company does not require their native English teachers to have a North American accent like <i>VIPKid</i> . They also offer online training courses for aspiring English instructors worldwide.	This is the main competitor of <i>VIPKid</i> , working along the same lines.
Dali smart lamp (ByteDance)	This is a smart lamp featuring a display, camera and built-in digital assistant. It is aimed at school children who can use the device to finish their homework. The camera enables parents to tutor their children and check in remotely via a mobile app.	Part of the new consumer hardware/education portfolio of ByteDance, the most valuable startup in the world and owner of social networks such as TikTok. <i>ByteDance</i> also owns, among others, GoGoKid to teach children English, and Qingbei, to replicate the class experience. According to company sources, more than 10,000 employees work in its education department
Hujiang (CCTalk)	<i>Hujiang</i> was founded in 2001, as a BBS (bulletin board service) community offering online courses but has since expanded to offer a wide range of online educational programmes, including international and domestic exam prep, foreign language instruction and professional skills training. CCTalk is its real-time interactive education platform to provide independent educators with online education tools and platform capabilities, providing content and a community environment for learning. The platform allows teachers to utilise and create educational widgets, including a two-way digital whiteboard, digital hand raising, a multiplayer video for teacher-student synchronisation, desktop sharing, live PPT-like courseware and playback functions.	
KaDa	This application belongs to the early learning segment (for children aged 0-3 years) and consists of children's songs, stories, picture books and animations. This is part of the wide belief of Chinese parents that their children should start as early as possible to have future success.	
Liulishuo	This belongs to the AI + Education category. It has developed the 'AI English Teacher' based on deep learning, which provides a personalised and adaptive learning path for every learner.	Startup with unicorn status.
NetEase Cloud Classroom	This education platform uses three different business models: either B2C, developing the courses by the companies themselves, or B2B2C, attracting smaller companies to share their content on the platform, or UGC where it is final users –checked by the platform – who develop and upload the content themselves.	

Case	Description	Remarks
Sanhao	This startup provides one-on-one or one-on-few online tutoring lessons, and online study materials, often with centralized course development.	In 2018 it received USD 150 million of funding.
Squirrel AI	<p>The company is an online course provider that aims to optimise students' daily learning sessions through an AI adaptive learning engine.</p> <p>The cognitive tutoring system aims to use AI to help children target their knowledge gaps accurately, figure out the root causes of test failures and make study plans. Every children registered on the platform receives individualised teaching suggestions of which 70% is compiled by an AI assistant and the remaining 30% by human teachers.</p> <p>Squirrel's most interesting innovation is in its granularity and scale. For every course it offers, its engineering team works with a group of master teachers to subdivide the subject into the smallest possible conceptual pieces. Middle school maths, for example, is broken down into over 10,000 atomic elements, or 'knowledge points,' such as rational numbers, the properties of a triangle and the Pythagorean theorem. The goal is to diagnose a student's gaps in understanding as precisely as possible. In comparison, a textbook might divide the same subject into 3,000 points; ALEKS, an adaptive learning platform developed by US-based McGraw-Hill, which inspired Squirrel, divides it into roughly 1,000. Once the knowledge points are set, they are paired with video lectures, notes, worked examples, and practice problems. Their relationships – how they build on each other and overlap – are encoded in a 'knowledge graph,' also based on the master teachers' experience. A student begins a course of study with a short diagnostic test to assess how well they understand key concepts. If they correctly answers an early question, the system will assume they know related concepts and skip ahead. Within 10 questions, the system has a rough sketch of what she needs to work on and uses it to build a curriculum. As the student studies, the system updates its model of their understanding and adjusts the curriculum accordingly. As more students use the system, it spots previously unrealised connections between concepts. The machine-learning algorithms then update the relationships in the knowledge graph to take these new connections into account (Hao, 2019).</p>	<p>The company is based in Shanghai and was founded in 2014.</p> <p>The company attracted as much as RMB 1 billion RMB in its series A funding in October 2018.</p> <p>The company also opened a joint research lab with Carnegie Mellon University in 2019 to study personalised learning at scale, with the aim of later exporting it globally.</p> <p>As of 2019, the company has opened 2,000 learning centres in 200 cities and registered over a million students. It plans to expand to 2,000 more centres domestically within a year.</p> <p>In total, the company has raised over USD 180 million in funding and at the end of 2018, it gained unicorn status (Hao, 2019).</p> <p>Squirrel is already in discussion with several schools in China to make its system the primary method of instruction.</p>
TAL (XRS)	This is aimed at learning maths through games.	
VIPKid	<p>This is aimed at students of English aged 4-15.</p> <p>The students are in China, but they are connected online to teachers in the US.</p> <p>The English teachers are considered independent contractors paid hourly.</p> <p>The education system is supported by AI systems to recommend areas of improvement for students.</p>	<p>The startup claims that, from 30,000 professors and 200,000 students in 2017, this remote video chat application grew to 70,000 professors and 600,000 students in 2019.</p> <p>The company was already valued at USD 3 billion in 2018.</p>

Case	Description	Remarks
		During the pandemic <i>VIPKid</i> offered 1.5 million free online courses to children aged 4 to 12 years old.
Xueersi	K-12 live streaming with group courses. Online lecturer with offline tutor and teaching assistant.	Specialised in tier 3 and lower cities.
Yuanfudao (Yuantiku)	The platform focuses on K-12 learning and its products include AI-enabled virtual classes, live tutoring and apps for homework support. In 2015, it launched <i>Yuantiku</i> , an online question bank. This app takes advantage of the test-taking focus of the education system in China, <i>gaokao</i> in particular. According to the startup, two thirds of <i>Yuantiku</i> 's staff is dedicated to research and development, in particular to further develop its artificial intelligence methods in more effective learning methods. However, since its release, there have been public debates regarding its promotion of the heavy test-centric culture still popular in China.	A start-up founded in 2012, <i>Yuanfudao</i> raised USD 1 billion in a new round of funding in April 2020 as a response to the coronavirus outbreak including its previous investor Tencent Holdings. This puts its valuation at around USD 7.5 billion, making it one of the most valuable EdTech start-ups in China. Approximately 13 million Chinese middle and high school students utilise the app for <i>gaokao</i> -related learning.
Zuoyebang	This is a homework tool combined with 'snap & search' question bank functions, and online K-12 tutoring services. It allows photos to be taken to get answers and also has live- streaming group courses.	In 2018 it received USD 850 million of funding and it has already reached unicorn status.

Source: own research

5.4 Support for the education system

EdTech is expected to greatly improve the efficiency of educational organisation. Technologies to support education systems include smart campus/school management, information security systems, cloud platforms, distributed multimedia learning resources, teaching support systems, education SaaS and instant feedback systems. They include processes such as registration, access control, surveillance, localisation, the identification of activities and even genetic tests to detect intellectual abilities. As a prime example, the same systems for face recognition in classes are used for scanning faces to pay for food in the canteen, enter and borrow books from the library and buy drinks from vending machines. All the main universities in China now use face recognition in halls, libraries and at events registration, a trend that the pandemic has only exacerbated.

Selected cases

Table 4 below summarises main cases of support for the education system. They have been selected because of their relevance and/or popularity in China as described in the table.

Table 4. Summary of support of the education cases

Case	Description	Remarks
China National Knowledge Infrastructure (CKNI)	CKNI is a database of academic journals and master and doctorate papers. Usually, students hand over the digital copyright of their theses as a condition for graduation. In addition, academics and journals similarly give up their copyrights. Journals rely on	CKNI was established in 1999 as a government-supported national digitisation project to allow access to research documents and journals. It is

Case	Description	Remarks
	CNKI for exposure and citations, which boost their domestic rankings.	owned by Beijing's Tsinghua University and its affiliated companies. By 2018, CNKI had grown to include nearly 1,300 exclusive top-rated journals and the most comprehensive database of master's and doctorate papers – nearly half of which are only available on CNKI. It claims to not just be the domestic market leader, but also to be the 'biggest academic database in the world.'
International Teacher Workshop	This institution promotes a project-based teaching system that runs through preschool, elementary, middle, and high schools.	This is an activity taking place in Shanghai (2 nd edition, 2-3 July 2019). It is aimed at excellent ('model') teachers from rural places in China and it is promoted by Chinese companies and the High Tech High School of the United States.
Mars Camp	Science-themed (STEM) camp education is the top choice for parents of elementary and middle school students. This market has been backed by local authorities encouraging schools to organise study tours and making it an important indicator of the schools' performance. <i>Mars Camp</i> is an example of such companies, using a location in a Tibetan prefecture in Qinghai province to emulate life in outer space and teaching students how to cope with it.	The total value of the study tour and camp education market was about EUR 13 billion in 2018 and 31 million students participate –with approximately 1 million sent overseas – and expectations to double by 2021. In 2018 about 30 startup companies in this segment had gained pre-Series A funding.
SenseTime	During 2019, the company released new products in the support of an education system such as a smart door pass that can identify more than 20,000 faces in real time. The smart door pass has a recognition failure rate of less than one in 10,000 even under dim lights, according to the company.	This is a unicorn startup, founded in 2014 by researchers from the Chinese University of Hong Kong and specialised in image recognition.
Small Step App	This essentially provides paid courses on parenting knowledge, early education methods and parent-child games.	This is part of the new trend of parenting information and parent-child co-learning activities.
Super Park China	The park includes areas for adventure, games, free activities and digital experiences for children and adults.	This is a Finnish park showcasing the country's educational philosophy. As of June 2019, it has two branches, one in Shanghai and the other in Suzhou (Jiangsu).
Two-teacher classrooms	Thanks to streaming services, rural students can watch lectures live together with students from top-level schools of education. This system is generally known as 'two-teacher classrooms' with one remote/online teacher and one local teacher. In a typical scenario, two-teacher classrooms invite high-quality teachers from tier 1 cities or native English-speaking teachers to offer courses remotely and local teachers help maintain the classroom and organise activities.	This can solve the imbalance in the supply of teachers between regions in China.

Case	Description	Remarks
WeChat (Tencent)	<p><i>WeChat</i> has elaborated on four focus areas. The first is a home service for schools and education bureaux which facilitates management such as uploading recorded lessons.</p> <p>The second is the cooperation of WeChat with their service providers to develop education applications.</p> <p>The third is a deep customisation function which seeks to meet the needs of individual students.</p> <p>The fourth refers to a smart hardware linkage in order to develop a smart campus.</p>	<p>During the pandemic, it released a 'smart education plan' to launch a 1-billion-yuan start-up fund encouraging schools and education bureaux to use WeChat's mini-programme for smart education innovations.</p>

Source: own research

EdTech during the pandemic

As happens every year, by the end of January or early February, China's schools close for the one-month holiday period known as Spring Festival. What nobody expected was that they would not be opened again until at least five months later, amongst a wide range of security and protection measures for the students. The global pandemic originated from the Covid-19 outbreak affecting all industries and countries. China was the first country to close schools: 27 January 2020, during a holiday period. For the institutions and teachers, they were forced to develop a whole new procedure while not being able to gather the materials left at the centres. The task was to create remedies based on the only available resources online to keep the existing school calendar functioning and maintain teaching quality. This was not the first time that a similar situation happened in China. As SARS-CoV-1 spread in early 2003, predominantly in mainland China and the special administrative region of Hong Kong, the Chinese executive formulated a comprehensive strategy to guard against infection. School closure was practiced as part of public efforts to contain the epidemic ('COVID-19 Education Response. Preparing the reopening of schools' (2020)).

From a broader perspective, China's response set a good example of what happened everywhere later on: the sudden shift to distance/online teaching happened providing little time for all educational agents involved to acquire, develop or improve their digital and social media skills.

6.1 The institutional response

The first date the authorities issued concerning returning to schools was 24 February but, as with many deadlines at that time, it did not happen. In fact, on 9 March, around 200 million students (primary and secondary school) started the new semester online. This has been the largest transition for a simultaneous online learning methodology. The initiative by the Ministry was called 停课不停学, which could be translated as 'stopping the course but not stopping the learning process' or 'ensuring learning while classes are disrupted'.

The main goals of this initial response were to create and launch an alternative online learning system, and to develop and elaborate a procedure to ensure the safe re-opening of schools and return of the students.

With regard to the first goal, in two weeks, the Ministry of Education partnered with the Ministry of Industry and Information Technology to organise conferences, involve schools' management agencies, online platforms, course providers, telecom providers, television channels and the remaining stakeholders from the education community.

The policies to be implemented around the online learning goal at the time were to:

- boost internet connectivity service for online education with under-served regions as the main goal using all major telecom service providers;
- upgrade the bandwidth of the National Cloud Platform for Educational Resources and Public Services³⁹, and the remaining major online education service platforms to be able to accommodate millions of students simultaneously;
- make available open and selected online materials and resources. In particular, 24,000 online courses for universities and 22 validated online platforms (Halsall, 2020), powered by artificial intelligence to primary and secondary schools;
- prepare new, flexible and efficient methodologies to facilitate the learning process. This included that schools and teachers could choose the content based on the local e-readiness (online platforms, TV programs, Smart TV selection of videos or mobile apps) and that teachers get training from teaching methodology through live-streaming, online tutorials and MOOCs;
- ensure online security: collaboration between the telecom sector, online platform service providers and regional departments of education; and
- ensure the delivery of content that provides psycho-social support to the population and content regarding the protection from the virus.

The mandate was clear: teachers had the rest of the holidays to train, get used to the new materials and prepare the second semester and resume online lessons as soon as possible. However, the Ministry of Education of China soon discovered the risks: vulnerable families and students from marginalised areas will struggle with

³⁹ <http://www.eduyun.cn/>

the risk of increasing inequalities between regions. Connectivity and device access were then made the priority, followed by the need to ensure enough teachers' digital skills.

China looked anywhere for resources. Together with UNESCO, it started curating and making available information, good practices, guidance and documentation. Chinese schools would use their own materials but also benefit from the edited materials from the EdTech Hub, mEducation Alliance, INNE (Inter-Agency Network for Education of Learning), among others. Harvard Global Education Innovation Initiative, HundrED, the World Bank Group of Education Global Practices and the OECD Directorate for Education and Skills would also be institutions in permanent contact with China's MoE.

With regard to returning to face-to-face education, the MoE coordinated the production of guidance documents for controlling and preventing the virus. They were drafted with the assistance and support of Peking University, Central South University and a group of other important institutions ('MOE issues COVID-19 control and prevention guidance for schools' (2020)). It was addressed to nurseries, primary and middle schools and higher institutions.

The guidelines⁴⁰ included five key measures to contain the pandemic:

- the pre-requisite was 14 consecutive days with zero new confirmed cases;
- parents need to feel safe sending their children to school;
- temperature measurements, facial recognition, staff members and all resources for the epidemic prevention and control are in place;
- the epidemic needs to be fully under control at least at county/district level; and
- all schools must meet the guidelines issued by the Ministry of Education.

Table 1 displays the resulting timeline for the implementation of these measures.

Table 5. Chronology of return to education in China during the pandemic

End of March 2020	Start of school reopening. Dates dependent on particular provinces. Priority to graduating students in secondary schools and vocational schools. Nurseries and special education institutions are dealt with in a more flexible manner.
April 2020	By end of the month, more than half of the provinces have reported to have already re-opened schools, mainly secondary but also a significant number of primary schools. Hubei province and Beijing's institutions remained closed.
May 2020	<i>Gaokao</i> is postponed for one month: to 7, 8 and 9 of July. By the end of the month 92% provinces have reopened schools for Grade 9 and Grade 12 in order to prepare for the national university entrance examinations (postponed for one month). Universities open with strong safety measures for the staff and admin personnel.
June 2020	86% of secondary schools were open and active. In Beijing, the second wave outbreak led to the closing of schools and education activities. The MoE started preparing the 2020-2021 academic year. Concerns from international schools and universities being unable to help their international teachers return. An invitation is required for the VISA and the price of the flights has risen dramatically.
July 2020	<i>Gaokao</i> is held in China. All international summer activities are put online or cancelled for the next year. The China Education Exhibition to be held in October 2020 is cancelled for this year.

⁴⁰ They are available at http://www.moe.gov.cn/jyb_xwfb/gzdt_gzdt/s5987/202003/t20200312_430163.html

August 2020	Beijing Municipal Education Commission issued the dates for the re-opening of schools. From 1 September it is expected that almost the entire country will return to normal activity. Foreign teachers' presence and most students from abroad to be delayed until the next semester.
Autumn Semester 2020	Semester will start in September 2020 in both schools and higher education institutions and the authorities' objective is to open around 90% of the institutions. Teachers are required to have prepared for a shift to online work in case another outbreak hits the educational centre.

Source: own research

This chronology barely depicts the extreme circumstances of those days, which included some teachers trapped in campus for three months and the physical and psychological consequences for some students who could not return home.

In any case, the authorities placed special emphasis on ensuring students' safety. As of September 2020, students still are required to present their Health QR code, always carry their ID cards, have their nucleic acid test report ready and get used to constantly having their temperature checked. Face recognition checkpoints and automatic temperature posts are now not only displayed in schools, universities and official buildings but also in many residential areas and streets which were not monitored before.

6.2 Platforms and resources

This section reports briefly on the most relevant EdTech platforms and resources during the pandemic. A full list is provided in an annex.

The most relevant of them all is the National Cloud Platform for Educational Resources and Public Services, already mentioned in the measures issued by the government. This platform provides cloud educational services to students from 6 to 18 years old. It hosts more than one million videos and includes the curriculum plan for the teachers to follow. It claims the contents have been created by the best practitioners and by specially awarded outstanding teachers. It covers primary schools, secondary schools and special education institutions.

The second EdTech platform is the National University MOOC⁴¹, also known as China's EdX. It contains a massive amount of free recorded courses at university level, sessions and practices from the best education institutions in China. It also provides a service for independent instructors (Reimers, Schleicher, Saavedra & Tuominen, 2020).

The third platform of particular relevance is NetEase Open Class⁴², the most recognised non-governmental MOOC platform in China. Only some of the courses are free. It also includes materials from world-class universities and other learning material, such as Ted Talks with Chinese subtitles (Reimers et al., 2020).

In general, the pandemic outbreak represented an opportunity for EdTech companies. Key firms, such as VIPKid, Yuanfudao, Makebloc and Changing Edu launched different initiatives to facilitate online learning during the pandemic: from initial free donations of subscriptions to special deals and extra content. According to Daxue Consulting, Yuanfudao increased its weekly users 21 times, and Xuersi grew 50-times larger compared to pre-pandemic. However, the preference of consumers for short commitments, such as one-month special prize subscriptions or interactive short-videos, casts some doubts about their market behaviour once the schools reopen.

In addition to content platforms, schools and teachers needed to choose a system and methodologies for online classes and educational management. The decision was based not only on the suggestion from a higher institution but also based on the users' own experience and the response from parents, teachers and the rest of the educational community. To this regard the variety in solutions was considerable (Kologrivaya & Shleifer, 2020).

Teachers during the pandemic may have opted for systems based on basic mobile phones if they thought their students were not able to get a better device. Additionally, in some cases they chose systems with strong offline

⁴¹ <https://www.icourse163.org/>

⁴² <https://open.163.com/>

functionalities (such as Kolibri) if they thought their students' connectivity was not good enough. In addition to MOOCs such as those already mentioned or the classic XuetangX or Khan Academy – very popular in China – they also choose websites from official administrations for learning languages such as the British Council or Instituto Cervantes, coding applications, free books and content provided by publishers, Amazon or other media platforms, tutorials and videos from Youku, Bilibili, Iqiyi, collaboration platforms with live video such as Laik, tools for communications such as Zoom, WeChat, Tencent Classroom or Tencent Meetings, and all the resources available for free from UNESCO, the World Bank and the Chinese executive.

In conclusion, from the institutions, platforms and resources perspective, the plan proved to provide a suitable framework, later implemented through a trial-and-error approach with the daily work of the education middle-managers and the teachers.

6.3 Teachers' perspective

All teachers interviewed agreed on the first task they faced during the pandemic: adapting the teaching methodology from offline to online. For the majority, that required reinventing the role of the teacher in the educational process and making changes to the entire learning dynamic. The key issue was understanding their own task as a facilitator and content curator, far from the previous content provider perspective. In this new scenario, the teacher was now required to create learning experiences designed to help the students learning strategies and competences.

Then, the second challenge was to be aware and conscious of the implications of the differences between offline and online education. Online teaching and learning require more than the digitalisation of previous materials made for conventional education. It is mandatory to reflect on the students' learning purpose, organise and curate the new materials.

According to teachers, motivation was initially key – and frequently underrated – to the success of online teaching and the learning process. Being in a classroom is such an immersive experience that, when converted to its online versions, could lead to distractions, uses of other programs or a complete dependency on an external factor, e.g. the parents. Consequently, it was also important to provide the students with tools to manage their own learning experience, in other words, help them with their autonomous management.

It becomes a double-learning process: the subject content and also the digital skills or capabilities from both the teacher and the students. An adaptation period was required for both parties to understand and improve the process.

The third task was then to start teaching and adapting what had been learned. It was time to acquire and implement procedures, techniques and good practices in order to not lose effectiveness and adapt to students' needs. In fact, most teachers agreed on having finally acknowledged their role not just as a content provider but as a motivational agent, a considerable departure from traditional forms of education in China.

Another important issue raised in the interviews was the controversy of having to commit to the courses' timeline: it was mandatory for the administration to keep the school calendar and to finish the course on time. On the one hand, students adapted faster to the new normal than teachers; on the other hand, this timeline was also the cause of the strong pressure related to their academic performance. Compared to the offline and physical lessons, teachers observed and commented on private meetings that the online system increased the pressure on the child's learning process.

Feedback from one-on-one conversations of teachers with some students revealed anxiety and insecurity related to whether they were learning effectively or not – or at least the way their parents/teachers expect. Teachers now fear this pressure could be something that will stay and become an inherent part of the online methodology.

Finally, all teachers agreed on interaction being the most important part of the online learning process. To this regard, most teachers relied on communication tools such as *WeChat* or *ZhiXueWang* instead of the educational platforms. It is a common complaint in most of the interviews: interaction is not the same comparing both. The quality of the connections and their own lack of skills mastering the platforms seem to be the main causes. Most approached this technological change as a quick fix to solve the immediate problem but not as a disruption to the way of teaching and learning. According to their explanations, the relationship between the teacher and the student is more important than content or methodology. According to the interviewees, in an online environment it is hard to strengthen that link and maintain the teacher's role as a model. The challenge lies in creating a learning experience where the teacher is able to guide the student. For that it is compulsory to master

the tool or the device where the lesson is being taught and of, course, it requires a delicate mixture of time and trust.

6.4 Learning outcomes

With regard to online education evaluation, there are some proposals to use data from applications to produce some type of evaluation, but so far there is no defined proposal nor result yet. However, since the government's priority is to re-open schools and return to the classic offline lessons in September 2020, the only possible evaluation lies in the very same criteria of every year: the *gaokao* marks. These marks showcase the best students, teachers and high schools and allows their marks to be checked to see whether there has been a significant increase or reduction because of online education. Available results show similar grades to past years, although it was not clear if the correction was somewhat less strict than in past years.

With regard to challenges and learning outcomes from the interviews conducted, Table 2 summarises the main results.

Table 6. Challenges and learning outcomes during the pandemic from the teachers' perspective

Challenge	Learning outcomes
Technical aspects/issues	<p>Ensuring each student has a device, even if it is shared with parents.</p> <p>Training teachers and students in accessing and discovering the means for access, methodologies and potential of every platform/app used in the course.</p> <p>A good connection is key, for both teachers and students.</p>
Screen hours	<p>Ensure both teacher and students have enough breaks, physical exercise and time away from the screen.</p> <p>Some teachers reported getting sick or students being affected by far too much screen exposure.</p>
Classroom hours	<p>For some students, this system became a 24/7 immersion in the learning process.</p> <p>Homework became the main activity and the government had to issue a recommendation to ensure students' wellbeing.</p>
Content edition/creation	<p>Teachers considering too much available content could be as bad as too little.</p> <p>Teachers had to find the right content and curate it in a pipeline that needs to work in a timely manner.</p> <p>Tutoring became essential as, depending on the student's personality, their learning path will be different.</p>
Homework	<p>The more adaptable, the better.</p> <p>The most successful teachers were able to put together two or three options.</p> <p>Manageable: students at home, dealing with confinement, need activities where they can feel confident.</p> <p>Easy to correct: many teachers reported that their working hours were more than before the pandemic.</p>

<p>Social aspects</p>	<p>The socialising and team-building function schools play in society is important.</p> <p>Teachers learned to encourage the group identity, build their inner strengths and study habits and make them feel part of group. The risk of isolation has psychological consequences.</p> <p>Tutors play a key role in building trust with students.</p>
<p>Time management</p>	<p>Most of the teachers consider it the hardest skill to master. Some of them reported working more than 50 hours a week during the pandemic.</p> <p>Lessons are supposed to encompass 45 min. Depending on technical issues or other circumstances they can last for longer. However, students spend more time than expected.</p>

Source: own research

From the interviews with teachers, the ample majority still preferred the offline lessons. Those who preferred online classes were equally divided between those who consider that online education still needs some improvement. However, it was a rewarding experience, and those who directly embrace it as the tool for the future reported that they would prefer to continue online. This is a considerable contrast to a survey from May 2020 ('2020 年在线教育报告出炉! 三方资本围猎, 下半场靠什么狂欢? (2020 Report on online education)' (2020)) that included 20,000 students, with 70% willing to continue with the courses and the education provided from the beginning of March.

6.5 Students' perspective

A significant number of students complained about the difficulties of getting used to the tools and the functions of the educational platforms. They will prefer to stick to their own apps or mainly use tutorials available in *Bilibili* or other platforms they were already used to.

Some proudly comment on how teachers need them for support. This could be considered a first and timid attempt at more collaborative lessons, with the students leading some activities in a more natural and organic exchange. Students comment on how this situation has changed their usually rigid and distant relationship with teachers. The online methodology somehow forced the educators to take more care of the students and ensure nobody is left behind. In other words: it forced them to be more empathetic. This closeness even raised controversy relating to the use of the webcam in class. Some teachers required it and asked the students to switch it on, so they can see their faces. Legally, that was not compulsory and most did not agree, with the support of their families.

Box 1 – A day at school in the post-Covid era

A typical average classroom in a public school in China might have around 40 students. Distancing within the classroom is generally not possible, therefore strong emphasis was put on prevention and follow-up measures. Students enter school through some type of tent tunnel equipped with automatic body-temperature measurement equipment or there is simply a person measuring each students' temperature with a wireless thermometer. If a child is suspected to be sick, they are sent in a separate direction for further testing. The tutor is called to pick up the child and if this is not accomplished in two hours, the child is sent to a hospital.

Initially, mask-wearing was compulsory and strict instructions were provided on how to use it during conflicting activities such as playing music or sports. In mid-May 2020, after some fatal accidents with students due to mask usage and also owing to increased control of the epidemic, China's Ministry of Education declared that students no longer needed to use masks if they were in low-risk areas, and most schools relaxed the rules. Some teachers stopped wearing masks, but nearly all the children kept them on when not engaged in demanding activities such as sports.

Schools scheduled regular hand-washing breaks and about five times per day students' temperatures were taken. Information on how to use masks together with social responsibility is provided through all available means.

Parents' *WeChat* groups were typically created per course or classroom. Parents were asked to provide information on their child every day including body temperature and health status. Staff from school would chase laggards and non-compliers.

More demanding measures such as reducing class size, remodelling facilities or outdoor learning are being reserved for possible future situations. When the virus is at risk of spreading out of control, lockdown and mass testing is preferred.

Compared to teachers, as expected, most students easily picked up the advantages of online education: it makes a remarkable difference from the ordinary timetables of a K-12 student. They would normally wake up around 5:30 am and study about 10-12 hours a day. Boarding students reported that this system caused them a dichotomy: on the one hand, it was more relaxed to avoid the extreme vigilance of the supervisor; on the other hand, they felt greater pressure on the need to be more autonomous and trust themselves when organising and managing their time.

On discussing students' progression with online tools, company experts feel certain about the long-term impact of this disruption. Most of them have a strong opinion on the teachers' profiles and skills. There was an explicit mention to not focus on the teachers, as it is maybe too late for most of them to change their methodology. For them, high hopes lie in those students who had been able to discover a wide range of tools, videos and other resources that will make them ask both parents and teachers for a change. According to this, they are completely certain of the competence enhancement and tech-savvy improvement for students and they have their increasing number of users as an evidence.

However, many of the EdTech company CEO's consulted for this report were very insistent on not overemphasising the importance of the pandemic on a hypothetical systemic change on education policy. There are two perspectives: some of them consider the rise of users during this season as a temporary fact that helps them provide some visibility; other thinks it is the beginning of a change that will still require strong guidance, policies and the support of the authorities.

Box 2 – A day at online university

Zoom is the preferred means for online classes at universities. An average class would have 60 students. Cameras are switched off to improve audio quality. Classes are recorded and available to students offline later. An assistant is provided per course to help professors with the class management. It is requested that documents and support material are provided to students beforehand. Evaluation is suggested to be based on individual work and groupwork.

Of the different aspects that students reportedly liked was the possibility of correcting the exercises, exams and tasks directly, via their app or new resources like *DingTalk*, which allowed them to view the content at their demand. The idea of being able to review as many times as necessary was commented as a great improvement. According to Huang Changfeng, from *Tencent QQ*, tens of millions of students were submitting their tasks everyday through their application. Such an experience compared to the previous handing over to the teacher, establishing a disrupting routine ('Smart Education in China: Ed-Tech firms seek new opportunities as pandemic eases' (2020)).

In conclusion, from the students' perspective, to a certain extent the greater progress the students made during the days of confinement was the possibility of having a more open and flexible system where the teacher's authority is important but does not play the unavoidable role as before. The anxiety and vertigo of this new system came not only from the pressure of the future grades, but also from the need to take control and assume responsibility for their learning process.

6.6 Effects on families

Research and one-on-one conversations with families revealed a vastly different situation from the ordinary success stories of change regarding the transition to online. Although most families were able to establish a well-divided methodology of tasks and communications, others, scared by the possibilities of their children getting bad marks or the possibility of losing face in the public groups, started some dysfunctional dynamics. Never officially, but parents complained privately about the amount of homework and confided that in some cases they were ultimately the ones doing it.

Communication was another main issue. This encompasses both parent-student communication and parent-teacher communication. In the former, it is a common trait for these generations of children in China to be raised by their grandparents. The latter has a closer relationship with the teachers, especially in the cases of the primary schools' students, who in some provinces like Beijing did not return to school until September.

In many reported cases, parents found it hard to help their children with the learning system. As they were returning to work, the children were again raised by grandparents with almost zero knowledge of technology. The most common consequence was the impossibility of being able to track and supervise their child's progress. A parent's lack of knowledge of the platform did not help to build connections with others through common tasks. This therefore has effects on the second channel: parents sometimes used education groups as a place to gather information, put pressure on their children by showcasing other children's development and also on the teacher regarding the amount of homework and their corrections. Teachers had to be responsible for this communication and, depending on the groups and the users involved, communication was more or less fluid. Most parents mentioned that these past months were a challenge as it forced them to change the dynamic of a familiar system, which prioritised work and professional development, and spend time at home managing a disruption for the whole family.

Since initial guidance was missing, some families struggled at the beginning of the implementation of the process. For some parents, the sole idea of their children finally being busy and back to something related to school was both a need and a relief.

Parental demand for more feedback was accepted and some platforms, such as *ClassIn*⁴⁵, incorporated a signature requirement from parents and some tools to raise awareness of the timetables and the agenda. *QQ*

⁴⁵ ClassIn is a platform for online teaching. It was launched in 2014. See <https://www.classin.com/en/>

also upgraded their functions and allowed group announcements and reminders for parents who may have missed information.

The last aspect relates to the domestic economy: despite the strong efforts made by the administration to ensure the students from the less economically favoured areas get access to educational resources, the gap between the country and the city has grown widened. Basic access to electricity and internet connections were the first steps to help studying online and they are still uncovered in some remote areas of China. In fact, some of the Chinese government goals regarding poverty alleviation were included in the motto 城乡教育一体化, which is the integration of rural and urban education, and which could be unreachable if there is no return to schools.

Conclusions

7.1 China leading

China is leading in the application of new digital technologies in most of the B2C sectors, including education. The interest in technology-enhanced education innovations in China is fuelled by a huge market demand and level of expenditure – families looking for success in education as a means for social progress – and by the government's push as a means to contribute to innovations required in its economy and society.

As a result, competition for education applications in China is fierce. Parents and schools willingly pay or adopt any method that could help their children or students. The Chinese share a firm belief in the potential of technology, having seen how much it has transformed the country in just a few decades.

China is a country where some of the most advanced experiments into the usage of EdTech are happening and, as a logical consequence, it is a place from which some of the key implications of the implementation of education technologies can be learnt and understood as well as learning from both mistakes and successes.

7.2 Drivers of EdTech

China's new technology plan leverages the momentum provided by both the authorities and private companies to move beyond the outcome that the market itself could provide. This is essentially because China has mobilised resources for technology sectors such as EdTech combined with a long-term vision of technological development. Existing market barriers also provide domestic companies with an edge over their foreign competitors.

There are six drivers of China's implementation in EdTech, adapting and widening Kai-Fu Lee (2018) conclusions: i) an abundance of data; ii) a loose framework to access and exploit data from users; iii) new entrepreneurship with companies aligned with the administration's interests; iv) growing technical expertise; v) a young market eager for technical novelties that could provide an edge in education; and, last but not least, vi) considerable public funding and support.

7.3 Structural limitations

However, the general implementation of new technologies in China face barriers such as patchy implementations, a lack of standards and compatibility of applications, administrative inefficiencies, technological limitations and conflicts of interest.

China's reforms reflect an influence from western countries. As Ogunniran (2020) states that 'this does not mean that the government takes a *laissez-faire* attitude towards all associated ideologies. The issues concerning ideology and politics become sensitive and, in some way, restricted [...]'. The same author asserts that 'China's practices of importing foreign models to modernise the higher education system and implement other reforms have followed a borrowing from the West what was useful without losing the essence of Chinese values. However, as the philosophies and ideas underlying Western higher education systems are often alien to Chinese traditional culture or ideology, the development of Chinese higher education may inevitably confront paradoxes and challenges'.

In the case of education, there are additional structural limitations related to the still predominant legacy approach to education, the lack of resources to measure quality, the pre-eminence of the results of admission exams for students above anything else, the lack of enough new technology-related talent for education and the lack of means to provide it locally.

In fact, there is a shortage of EdTech-related talent and a concern of how to ensure that the local education system is able to supply well qualified professionals, as the virtuous circle of high school education in China, education at prestigious foreign universities and later recruitment for a high-end expert talent position in China may not suffice. Here, universities in China are required to play a pivotal role, not only by training new scientific and technological talent, but also by conducting basic research. This means moving beyond the focus of increasing the sheer number of students and placing greater emphasis on the quality of education (Zhang, 2018).

The difficulties of increasing the pool of talent are also related to the knowledge and skill set needed to succeed in the application of technology to education and the shortcomings of the existing education system. The issue at stake here is how to build 'functional specialists' in EdTech that are capable of continual customisation and

improvement, able to understand the application domain, needs and expectations, as well as determine which is the best approach (Baccala et al., 2018).

7.4 Permanent change and experimentation

The administration, aware of these limitations, promotes changes in the education system that, initially, take shape as local experiments, later extended nationally if successful. The innovative experiments are part of the national competition between regions, cities or even neighbourhoods for talent and improved education, particularly from second-tier cities that want to enhance their position. These experiments usually follow the logic of using the initial weak enforcement of privacy and ethical frameworks (top-down implementations with some room for innovation and adaptation) and then, depending on their usefulness and the society response, are either extended, reformed or discarded altogether.

Throughout the text there are interesting examples of the experiments currently taking place. Advanced education and in-class applications are still primarily in the initial stage of trials, while beyond classes EdTech is being reformed as these conclusions are written. The innovations for support of the education system have been already extended as they are felt as just the implementation within the education sector of already existing solutions used in other domains (like work, e-commerce...).

In addition, new plans for the reform of the education curriculum at all levels now exist with provinces and cities eager to implement them and gain the advantages of first movers in the attraction and creation of talent. Within them, (national, regional, local) administrations in China contribute to the conditions (plans, strategies, regulations, room for experimentation) and the practical support (R&D funding, venture capital, subsidies, purchases, access to data, tax breaks, lax individual rights protection) for education innovations to happen. And China's technology firms are aligned with authorities' interests in the combination of convenience, efficiency, personalisation and surveillance leading to social engineering currently taking place in China.

7.5 Learning opportunities

The first domain of potential learning from the Chinese experience is linked to infrastructures – generally a leading sector in China due to its vast size and economies of scale – and refers to connecting classrooms and deploying digital devices and even content with 5G, virtual reality, robotics, IoT and possible linking with schools in remote areas or sparsely populated regions. However, infrastructures and equipment to support certain tasks related to surveillance, access control and real-time monitoring of students within classes are of less interest from a European perspective.

A potential source of learning for China from Europe would be related to helping education institutions, teachers and learners to acquire digital skills and methods and validate them (e.g., *SELFIE*, the Self-reflection on Effective Learning by Fostering the use of Innovative Educational technologies⁴⁴). Digital skills have been considered a key competence in Europe in different frameworks for two decades (Carretero, Vuorikari, Punie, 2017; European Council, 2018, 2006). This is also a challenge for China. Mutual exchange of frameworks, platforms, methods and validation schemes could be of interest.

Commonalities in the mobilising of all stakeholders (teachers, learners, families, economic and social partners) to change the role of digital technologies at education institutions may be found mainly in the 'beyond classes' segment, most probably in language education and education related to software programming. Here, China enjoys a head start and a large market.

Open education resources (OER) is another field of innovation education that both EU and China wish to foster, although OER may be restricted by different administrations in the latter. Nevertheless, the use of OER in adult education might be more promising in China, where there is a prevalent attitude towards the relevance of lifelong learning for career development, of self-improvement and of remaining competitive on the job market. In addition, the regulatory framework for adult online learning is less restrictive than that for compulsory education. Adult education could cover degree education, MOOCs, lifelong learning – an area of high expertise for the EU – and foreign language learning.

Another area of potential mutual learning could be in the realm of adaptive education with the support of AI, in particular for those students in need of additional support from tutors. Here, education equality goals,

⁴⁴ https://ec.europa.eu/education/schools-go-digital_en

irrespective of location and income, together with enhanced quality and the reduction of costs facilitated by EdTech could be shared between China and Europe.

7.6 Conclusions from EdTech during the pandemic

The first and most important conclusion is the decision by the executive to come back to the offline method of education as soon and as much as possible despite the considerable success of the online education during the pandemic.

Government and society prefer standard education in the classroom for a number of reasons of educational (not as efficient as the classic model, need to be regulated and evaluated), social (only chance of socialising for one-child families, strict control), cultural (meritocracy, equal opportunities, competition) and economic (parents working all day) nature.

The learning outcomes during the pandemic have been different depending on the perspective of the stakeholder. From the institutional perspective, China had considerable success in the shift to online education as a substitutive/emergency educational technology. After the shock and some initial confusion, a rapid response through a coordinated initiative between ministries and internet infrastructure providers allowed almost any student and teacher to connect and learn from anywhere, at any time. Other incentives were then launched to encourage companies to devote more resources to education applications. In addition, public policies promoted free content through official platforms.

From the teachers' perspective, the main issues were their need for training in digital skills and platform management, their need for an adaptation period and the lack of interaction with the new technology versus the real classroom. Teachers, once they fully understood the new situation, first needed to adapt methodologies to online education, but during the process also realise that online education is more demanding than traditional. It required changes in the design of classes, the need for management of the virtual classroom and issues related to privacy such as the use of cameras. Educational managers also realised that for many professors their knowledge was mostly at user level and not at content creator level. All in all, tools that allowed for features such as 'raising hands', sharing the screen, conducting polls, drawing on the screen, sharing documents and co-editing functions were preferred by both students and teachers and not just educational content platforms.

From the students' and families' perspective, the main issues relate to the parents' pressure on students since a positive evaluation conditions the future opportunities for children in China. Officially evaluated by the scores of *gaokao*, students achieved similar marks as previous years. Therefore, they did not lose much during these months as they were kept busy by their parents taking extracurricular online classes or by accessing engaging online educational content through their mobile devices while quarantining at home and since there was probably some extra help with the evaluation to minimise the consequences of this troubling year. Students reported to have easily adapted to the online tools and have become more aware of new methodologies and the possibilities for education on their devices.

From an EdTech perspective, online learning will continue to grow as parallel and complementary education. It complemented the successful return to the classrooms in September 2020. Technologically, the pandemic has quickened the pace of cloud adoption, both to support near-term activity and to increase agility to withstand future challenges. In the mid- to long-term, experts suggest that the road forward is the merge between offline and online education (Lyu & Yang, 2020), creating an opportunity for the EdTech Chinese ecosystem to export this model globally.

7.7 Potential learnings from China

Potential learnings of significance from the experiences of EdTech in China firstly come from the misalignment of parents and education system interests with those of children and, therefore, seem to require some type of regulation or at least delimitation of boundaries between stakeholders.

In fact, a common agreement on the objective evaluation of EdTech in Europe could help in the development of key competences – and not just pure knowledge – such as resilience, creativity, empathy, social-emotional learning and active citizenship, with a view towards the positive impact on well-being as well as performance (Donlevy, Van Driel & Hoareau McGrath, 2019).

To this regard, China has declared its interest in cooperating to set such types of evaluations, although it is worth noting that critical views regarding the implementation of disruptive EdTech applications – even if on the rise – are still relatively low key and take good care not to provoke disloyalty in a policy that is highly supportive

of new technologies. It must also be noted that, while the calls for policy support voiced in the EU and the US focus on algorithmic transparency and accountability (Garfinkel, Matthews, Shapiro & Smith, 2017) and warn about moral responsibilities outsourced to algorithms, in China the focus is more about placing new technologies within the scope of the rule of law (People's Daily, 2018; Tan, 2018).

The combination of dissimilar objectives between China and other jurisdictions, and its interest in developing its own path in technology, has so far caused EdTech innovations in China to develop relatively independently from other countries and with limited connections with Europe. In terms of opportunity, any step in the direction of cooperation with China could be relevant since there is almost nothing except for several private initiatives.

Another finding of interest, already mentioned within mutual learning areas, is that China is embarking on a combination of technology and human resources to try to reduce the education divide between poverty-stricken / lack of infrastructure areas and more affluent (usually urban) zones (Li, 2019). Owing to the vast size of this market (and the associated problems) in China, it is expected that Chinese providers will issue affordable and technologically advanced innovations of interest.

To this regard, China's EdTech is currently most developed in the areas of image, face, text and voice recognition, together with their supporting techniques, such as machine and deep learning. It is true that in general China's pursuit of intelligent education still emphasises standardised learning and testing, making any progressive pedagogical system based on new technologies more difficult. However, at the same time, China's interest in education and its combination with technology is much more open to new innovations, and that if these innovations succeed, they will be rapidly extended.

Looking into China's leading applications based on adaptive learning supported by technology, they can be highly effective at understanding exactly what students know and do not know. However, they pay less attention to what they want to know or how they learn best. According to Professor Treviranus (Hao, 2019), there are three elements in future personalised learning innovations to improve inclusivity in education: pace, path and destination. If the pace of learning is personalised, students with different abilities are allowed different amounts of time to learn the same material. This is an area where technology is already happening, in China in particular. If the path is personalised, students might be given different motivations to reach the same objectives and offered the material in different formats. If the destination is personalised, students can choose the real-world goal for their education. Current implementation of EdTech in China is mainly characterised by putting all the students in the same standardized position and training students on structured knowledge.

Overall, in terms of using new technologies, such as AI, for fostering transversal skills such as collaboration and teamworking, creativity and imagination, critical thinking and problem solving, the focus in China is mainly on the latter.

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Annex 1. Code of conduct for teachers

Teachers are the engineers of human souls and the torch carriers of our civilization. Teachers have been a tremendous force in our nation's great cause of rejuvenation and development by upholding the Communist Party of China's (CPC) education policies and committing themselves fully and completely to a great endeavour called education. The new era has brought even greater job requirements for teachers. They need to be more responsible, have a deeper sense of duty and honour, demonstrate appropriate behaviour, draw a clear moral line in their conduct and be teachers that have faith, expertise and heart. Their purpose is to develop talents that are morally sound, intelligent, healthy and hard-working, and who can carry on the great cause of developing our socialist country. To realise this purpose, the following code of conduct is hereby set for teachers:

1. Take a firm political stance. Teachers shall be guided by Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era, uphold the leadership of the Communist Party of China and follow the CPC's policies on education. In their education or teaching activities or indeed on other occasions, they shall not express views that would undermine the Party's authority and contradict the Party's guidelines and policies.
2. Love our country and follow its laws and regulations. Teachers shall be loyal to our country and the people, follow the fundamental principles of our constitution and laws and regulations and fulfil a teacher's legal obligations. They shall not do anything that would harm the national, social and public interest, or breach social conventions and order.
3. Communicate ideas of merit. Teachers shall be the role model in practicing the core values of socialism, advocate integrity, kindness and inner beauty and demonstrate and pass on positive energy. They shall not express or relay inappropriate ideas in classes, lectures, forums, or through the internet and other channels, nor fabricate and spread false and degrading information.
4. Commit to education and the development of talent. Teachers shall take the development of talent as their ultimate goal, respect the educational rules and the growth of individual students, teach with each student's uniqueness in mind and learn from students. They shall not be undisciplined or careless in teaching or participate in part-time jobs that would impact their teaching performance.
5. Love and care about students. Teachers shall be strict with students but also demonstrate their love for them, teach and inspire them, genuinely love and care about them, hold them to the highest standards and be both the teacher and a friend to them. They shall not involve students in activities that have nothing to do with teaching and learning, research and development or social services.
6. Demonstrate integrity in language and behaviour. Teachers shall be the role model for students, be polite and righteous, have an outstanding character and self-respect. They shall not develop any inappropriate relationships with students nor engage in any forms of sexual misconduct or harassment.
7. Comply with academic rules. Teachers shall have a careful and genuine attitude toward academic activities, be patient with and have a commitment to academic development, be courageous in academic exploration, have an academic conscience, and raise concerns about any academic misconduct. They shall not copy, plagiarise, alter or simply use any academic work that is not their own, nor abuse their access to academic resources and influence.
8. Be fair-minded and honest. Teachers shall uphold their professional principles and be fair-minded and transparent in dealing with others. They shall not engage in fraud or engage in favouritism, including but not limited to admissions, examinations, recommending candidates for awards or undergraduate students for graduate admissions, employment, performance measurement, hires, evaluating and granting job titles and nominations for external awards and prizes.
9. Do not engage in corrupt practices and be self-disciplined. Teachers shall hold themselves to the highest standards, and not engage in corrupt practices. They shall not ask for or take bribes from students or parents; shall not engage in any activities, such as banquets, travel, leisure and entertainment events that are paid for by students or parents; and shall not use resources provided by parents to make profits for themselves.
10. Contribute to society. Teachers shall fulfil their obligations to society, contribute their intelligence to societal development and have a balanced opinion about personal benefits and benefits to society as a whole. They shall not use public resources for personal gains, nor use school resources, such as the school name, logo, patents and places, to make profits for themselves.

Annex 2. Questionnaire for interviews

Foreword

Thanks for being part of this survey and the report research. I will email you the preliminary result and the final results. Your name and position will not be showcased to the public. Only the data from your answer will be processed anonymously.

Thanks for your help and do not hesitate to contact me at: (email)

Name/position and institution: (tbc)

Questions

From the institutions' perspective, China was the first country to close and re-open schools. There were various platforms for online teaching:

In your opinion, which ones do you expect to remain in the 'new normal'? Which ones may disappear?

Which ones were best adapted to the teachers, students and market's needs in the previous months?

From your perspective, what are the learning outcomes in China from the pandemic?

From the teachers' perspective. Teachers have a direct experience, from the first line of action, the effects of the pandemic:

- Can you evaluate how much the student are learning or losing during these months?
- Has there been any formal evaluation from the government?
- Are teachers going to be evaluated too? How did they perform during the pandemic in your view?

From the students' perspective:

- How have the students progressed during the pandemics? Are they now more tech-savvy?
- Did they have the chance to access more innovative education: coding, robotics, etc.?
- Was there a curriculum or evaluation standards adapted to the current situation?

A glimpse into the immediate future:

- How will the 2020-2021 year be organised? More blended learning? More online?
- Does China want to get back to offline lessons? Will the rise in online teaching and EdTech help innovation in education?
- What can governments do to support EdTech and a change of the educational model? How can equity and equal opportunities be ensured? How can excellence and high expectations be reached?

Annex 3. Online resources used in China during the pandemic

<p>Digital learning management systems</p>	<p>CenturyTech ClassDojo Edmodo EkStep Google Classroom Moodle Schoology Seesaw Tools Tencent Ketang 腾讯课堂 Yunduo Ketang 云朵课堂 Dingdingkaike 叮叮开课 APA 网校系统 Vkjjiang 微开讲 Keshuo 课桌 Duobeiyun 多贝云 Zuoyebang</p>
<p>External repositories of distance learning applications</p>	<p>Common Sense Education Commonwealth of Learning EdSurge European Commission Resources Global Business Coalition for Education UNEVOC Resources</p>
<p>Tools for teachers to create digital learning content</p>	<p>Thinglink Buncee EdPuzzle Kaltura Nearpod Pear Deck Squigl Trello</p>
<p>Collaboration platforms that support live video communication</p>	<p>Dingtalk Feishu/Lark Hangouts Meet Teams</p>

	<p>Skype</p> <p>WeChat Work</p> <p>WhatsApp</p> <p>Zoom</p>
MOOCs	<p>Alison</p> <p>Canvas</p> <p>Coursera</p> <p>EdX</p> <p>iCourse</p> <p>Future Learn</p> <p>Icourses</p> <p>Udemy</p> <p>Udacity</p> <p>XuetangX</p> <p>YY 教育</p> <p>NetEase 网易云课堂</p> <p>Qingbeiwangxiao 清北网校</p> <p>Tencent Ketang 腾讯课堂</p> <p>iCourse360 中国大学 MOOC</p> <p>CNMOOC 好大学在线</p> <p>TopU 顶你学堂</p> <p>DuoBei 多贝</p> <p>CCTalk</p> <p>Xueersixiang 学而思想</p>
Video platforms	<p>Kuaishou https://www.kstv.com/</p> <p>Bilibili https://www.bilibili.com/</p> <p>Youku https://www.youku.com/</p> <p>iQiyi https://www.iqiyi.com/</p> <p>Douyin</p>
Direct learning	<p>British Council</p> <p>Byju's</p> <p>Code.org</p> <p>Code Week</p> <p>Discovery Education</p> <p>Duolingo</p> <p>Facebook Get Digital</p> <p>Khan Academy</p>

KitKit School
LabXchange
Mosoteach
OneCours
Profuturo
Polyup
Quizlet
VIPKid
Meishubao 美术宝
Hualala 画啦啦
Yangcong Maths 洋葱数学
Gogokid
Xueersixiang 学而思想
Code Planet 代码星球
Banmaaike 斑马 AI 课
Kuaipeilian 快陪练

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