Impacts of COVID-19 on primary, secondary and tertiary education: a comprehensive review and recommendations for educational practices

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Abstract
COVID-19 lockdown has caused disruption to education of all levels with far-reaching implications and unveiled the shortfalls of the current education model. Cycles of tightening and relaxation of COVID-19 lockdown confer uncertainty to the continuity of education. This article aims to comprehensively present the impacts of COVID-19 on primary, secondary and tertiary education and propose sound educational practices in the COVID-19 era. Papers related to educational impacts and implications of COVID-19 were selected for this review through a PRISMA model. The review shows that a shift of learning remotely or online has affected educators and learners, especially in relation to learning loss among learners, limitations in instructions, assessment and experiential learning in virtual environment, technology-related constraints, connectivity, learning resources and materials, besides psychosocial well-being. These impacts are exacerbated by inequalities in the distribution of resources as well as inequities attributed to socioeconomic status, gender, ethnicity, learning ability and physical conditions. The recommendations for future educational practices comprise adaptability of curricula to embed independent and online learning options, concurrence of diverse learning modalities for seamless learning transitions and flexibility, flexible staffing and learning model, enhanced support, technological and curricular innovation with simplification and standardization, as well as interactive, responsive and authentic virtual environment. This review contributes significantly to enhance preparedness of education to crisis while ensuring continuity and quality of education in the era of COVID-19 uncertainty.

Keywords Adaptability · Disruption · Online · Learning · Modalities · Remote
1 Introduction

Coronavirus disease 2019, more popularly known as COVID-19, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was first reported in Wuhan, China on December 8, 2019. Since then, it has spread quickly to different parts of the world (Tang & Chin, 2021). As of July 15, 2021, 08:11 GMT, 189,190,520 people were infected by COVID-19 globally and 4,074,788 deaths were reported (Our World in Data, 2021). Lockdown has been initiated at the onset of COVID-19 and has been adaptively implemented in different countries depending on the number of COVID-19 cases. Many countries have undergone cycles of tightening, relaxation and lifting of lockdown. During the writing of this paper, there were countries in tightened lockdown such as Malaysia, Bangladesh and Indonesia while lockdown relaxation was reported in China, Singapore, Brunei and New Zealand (Tang & Chin, 2021).

The control of COVID-19 has multiple impacts on the socioeconomic systems. Lockdown has resulted in the temporary and selective closure of businesses and services which prompts employers to adopt different employment patterns, for instance, by partially or entirely shifting from full-time employment to part-time and casual employment in relation to operational demands during various stages of COVID-19 lockdown (Fana et al., 2020; Tang, 2021a). The uncertainties brought by COVID-19 lockdown on businesses has an impact on the workforce, causing a significant reduction in the demand for workforce in sectors most affected by the lockdown, particularly hospitality and aviation (Fana et al., 2020). Self-isolation and travel restriction as a result of COVID-19 lockdown have catalyzed the deployment of online operational mode in many sectors such as education, retails, food and beverages as well as banking (Fairlie & Fossen, 2021; Tang, 2020a). Concurrently, it has affected the financial security of many, including employees and freelancers who rely on daily wages, as well as operators of nonessential sectors whose businesses are often forced to stop as lockdown tightens (Fairlie & Fossen, 2021). Without stable incomes, anxiety mounts, leading to distress especially in low-income families (Every-Palmer et al., 2020).

The education sector has been hard-hit by COVID-19 since the very beginning. While different countries have different policies on the operation of education centers, many education centers have been closed since the onset of COVID-19 (Tang, 2021b). On February 17, 2020 with COVID-19 more prevalent in China than other regions of the world, only Mongolia had implemented country-wide closure of education centers while those in China were partially open. This affected 999,014 learners (UNESCO, 2021). Two months later on April 20, 2020, education centers in 151 countries were closed, affecting a total of 1,437,412,547 learners (UNESCO, 2021). With the control of COVID-19 progressing differently in different countries, the number of education centers that remains closed at any one time differs. To reduce the impacts of COVID-19 on learning, education centers particularly higher learning institutions were quick to roll out online learning (Kundu & Bej, 2021). Students were hurried to online learning platforms and educators who had been engaging in face-to-face teaching would have to adapt to online teaching within a short notice (Kundu & Bej, 2021). The transition to online teaching and learning, in many instances, occurred in too short a timeframe to permit systematic and organized continuation of teaching and learning (Truzoli et al., 2021). The transition was particularly challenging for courses which require experiential learning such as field trips, experimental work and hands-on at all levels of education (Barton, 2020). However, the mandatory closure left educators with limited options, particularly in the execution of teaching and
assessments. In many instances, examinations needed to be canceled, postponed or replaced with other forms of assessment (Rolak et al., 2020).

On a positive note, the necessary shift to online learning has been instrumental in opening up new horizons in learning. It promotes the development of online teaching and learning platforms and tools, as well as online courses (Adedoyin & Soykan, 2020). It reveals that certain face-to-face educational elements could be moved online and certain courses could be delivered entirely online (Adedoyin & Soykan, 2020). It is beneficial in catalyzing the maturation of online learning which has already been implemented and advocated as a form of flexible learning for part-time learners or learners who favor such flexibility without being geographically bound (Adedoyin & Soykan, 2020). However, online learning also strips much treasured collaborative learning experience and the school or college life from some learners (Putri et al., 2020; Tang, 2020b). There have been numerous studies that probed the impacts of COVID-19 on education of different levels, often regionally and program-specific. Hanson et al. (2020) investigated self-perceived impacts of COVID-19 among medical students in the US on their application for urology residencies. Brammer and Clark (2020) reflected upon the impacts of COVID-19 on tertiary management education and the ensuing opportunities. Tiwari et al. (2020) employed a qualitative approach in studying educators’ views on the challenges associated with tourism education and revealed the need for educators to be well-versed in delivering the courses through different modes while keeping the curriculum updated. In an editorial, Carolan et al. (2020) underscored the shift of nursing education toward student-centered e-learning that could yield neutral or positive academic outcomes but there are barriers such as learning space, isolation, course structure and inadequate institutional support that need to be overcome to optimize the outcomes. A short review by Deery, (2020) on dental education in the US warned of the challenges in producing competent graduates especially with clinical teaching suspended or continued with implementation of social distancing. While this challenge could be overcome by technology, the support of appropriate education methodologies is crucial. Aristovnik et al. (2020) conducted a large-scale survey among tertiary-level students of 62 countries on their perceptions of the impacts of COVID-19 on their lives and found they were satisfied with the support provided by universities in online learning but faced a lack of computer skills and higher workload.

It now emerges that most of the studies on the impacts of COVID-19 on education focus on tertiary-level education and are frequently discipline-specific. The studies are survey-based or qualitative based on personal reflection. There are very few studies examining the implications of COVID-19 on primary and secondary educations. Engzell et al. (2021) assessed if school closures due to COVID-19 had an impact on primary school performance and revealed a learning loss equivalent to one-fifth of a school year. The loss was more significant for students from less-educated families. An experiment by Pozo-Rico et al. (2020) examined if teacher training program as an intervention to primary education during COVID-19 era was beneficial to teachers. This study showed teachers who underwent the program were better able to cope with stress and ICT. Nonetheless, it does not investigate the direct impacts of COVID-19 on the facets of primary education. Similarly, there are few studies looking at the effects of COVID-19 on secondary education. Hou et al. (2020) administered a survey among senior high school students in rural China on their self-reported mental health. This study disclosed that high proportions of students reported symptoms related to depression, anxiety and post-traumatic stress disorder, as well as suicidal ideation. Some were even inclined toward suicidal attempt. Truzoli et al. (2021) studied the impacts of self-reported risk and protective factors on online teaching implemented after the COVID-19 outbreak through questionnaire and unveiled depression,
stress, locus of control and self-efficacy as important determinants of online teaching satisfaction. High school teachers were the subjects of the study instead of students. A study to investigate how high school students spent their quarantine period during COVID-19 was performed but it did not delve into the educational impacts of COVID-19 (Asanov et al., 2021).

Numerous reviews of the impacts of COVID-19 have also been performed but they are frequently based on reflections and limited literature besides being region-specific and program-specific (Bokde et al., 2020; Brammer & Clark, 2020; Deery, 2020). There is a lack of comprehensive review that collates the major studies undertaken in this domain to present the impacts systematically and generate new insights. This review aims to comprehensively examine the impacts of COVID-19 on various levels of education, particularly primary, secondary and tertiary. From the review, it aims to highlight the emerging education trends in the COVID-19 era and propose sustainable educational practices which can help education centers to weather the storms of COVID-19.

2 Methods

To achieve the aims stated, this review referred to scholarly articles comprising primarily journal articles and secondarily conference papers published since the initiation of COVID-19. It also involved visiting official websites to gather latest data and statistics to reflect certain educational impacts such as the closure of education centers. It utilized scholarly databases, namely Web of Science, Scopus and ProQuest to source the relevant articles. The keywords used ranged from COVID-19, educational impacts and education implications to primary-, secondary- and tertiary-level education. The major findings from the review were presented in comprehensive tables. A PRISMA model typically employed for systematic review of intervention studies was adopted in this review (Stovold et al., 2014). Figure 1 shows the process of selecting literature based on the PRISMA model. The inclusion criteria are: (1) the articles must be solely related to COVID-19, not other...
outbreaks; (2) the articles must be published in English; (3) the articles must be related to the educational impacts of COVID-19, in line with the objective of this study; (4) the articles must focus mainly on primary, secondary or tertiary education or a combination of those since this paper examines the educational impacts of COVID-19 with a generalist approach. Articles of primary education which were extended to pre-primary education were also included; (5) the articles were published in peer-reviewed journals or conference proceedings to ensure the quality of the findings; and (6) the articles must contain recommendations for reducing educational disruption during the era of COVID-19 for the formulation and synthesis of recommendations in this paper.

This review excluded papers which discuss educational impacts due to outbreaks other than COVID-19, those related to pedagogical development of online or remote learning as well as those related to impacts on research, professional development and education system without making distinction of primary, secondary and tertiary education. Papers focusing on containing COVID-19 at educational institutions were also excluded. The major findings of the papers reviewed and the associated implications were subsequently summarized. The summaries were tabled based on levels of education. Papers covering both pre-primary and primary education were grouped under primary education, while those covering both primary and secondary education were grouped based on the predominant contents.

3 Impacts of COVID-19 on primary education

Pre-primary and primary education around the world has been disrupted by the sudden closure of schools during the COVID-19 lockdown. As there are limitations in involving pre-primary and primary school students in surveys, almost all the surveys conducted to identify how COVID-19 has impacted pre-primary and primary education were targeted at teachers and parents (Moss et al., 2020; Pensiero et al., 2020; Polydoros & Alasona, 2021; Putri et al., 2020). Non-survey studies revolved around quantification of learning gain or loss, and academic achievement through modeling. Figure 2 shows a list of the impacts and the number of studies reviewed which discussed the impacts.

From learning viewpoint, this review pointed to learning loss or slower learning gain among primary school students (Fig. 2) (Pensiero et al., 2020; Tomasik et al., 2021), particularly those of disadvantaged schools (Gore et al., 2021). In New South Wales, Australia, more advantaged schools actually reported 2-month additional growth in mathematics learning of Year 3 students (Gore et al., 2021). This implies inequality between students’ learning in the virtual environment.

In terms of learning, most studies reported an increase in screen time as well as challenges with technology and connectivity, in both developed and developing countries (Putri et al., 2020) (Timmons et al., 2021). Technological challenges frequently related to a lack of the necessary skills and equipment for online learning particularly in families with multiple schooling children while connectivity centered on internet and WiFi availability and speed for optimal learning experience (Fig. 2) (Aliyyah et al., 2020; Putri et al., 2020). Children from advantaged families had more learning time than those from disadvantaged families (Pensiero et al., 2020). There were also numerous challenges faced in teaching. Besides technology, connectivity and more screen time due to learning, teachers found resources and tools limited and they felt constrained in applying the diverse teaching methods and covering all the curricula they would in physical classes, as well as administering
assessment (Aliyyah et al., 2020; Polydoros & Alasona, 2021; Putri et al., 2020). In the UK, the priority of teachers during school closure shifted from teaching to supporting remote learning, health and well-being of students. This included ensuring students of disadvantaged families had enough food and could learn without online access (Moss et al., 2020).

From parents’ perspectives, remote learning was time-consuming and they found themselves having to tend to the needs of their children who were engaged in online learning (Fig. 2) (Timmons et al., 2021). They were also concerned about the quality of teaching which aligned with teachers’ view of difficulty in engaging students as well as limitations in employing diverse teaching methods, choosing the right tools and teaching online effectively (Aliyyah et al., 2020; Polydoros & Alasona, 2021; Putri et al., 2020; Timmons et al., 2021). In terms of psychosocial well-being, resorting to remote learning has been reported to strip students of communication with peer and teachers as well as their social life (Fig. 2) (Putri et al., 2020). Confining to their homes during school closure negatively affected their physical activity, eating habits and quality of sleep (Siachpazidou et al., 2021). Moving to remote learning also produced psychological impacts among teachers due probably to increased workload and the challenges encountered with remote teaching and it was revealed that intervention via teacher training could alleviate their anxiety, skepticism, fatigue and adaptability to ICT (Pozo-Rico et al., 2020).

In primary schools, it was particularly challenging to gauge the psychological impacts of remote learning on students because they might not be able to articulate their psychological conditions well in addition to the regulations on their involvement in surveys. Such impacts were often drawn from parents or teachers. Supports to students and teachers during school closure were widely advocated with special attention to disadvantaged students due to inequalities and inequities (Fig. 2) (Gore et al., 2021; Pensiero et al., 2020; Polydoros & Alasona, 2021; Timmons et al., 2021). Inequalities and inequities which opened up to a host of other problems such as accessibility to internet, learning resources and reasonable learning environment were brought to the limelight. The former often refers to the

Note: Some papers may discuss more than one impacts

Fig. 2 The impacts of COVID-19 on primary education identified from the papers reviewed (n = 10)
unequal distribution of or accessibility to resources among societal groups while the latter touches on the conditions leading to inequalities such as corruption, poor governance and marginalization. While educational inequalities were a matter of concern, the underlying inequities were equally alarming. (Pensiero et al., 2020; Tomasik et al., 2021). Most studies did not make a distinction between the two facets. There was generally a call for differentiated instructions in teaching and argument about synchronous and asynchronous teaching but a lack of research on the pedagogy for online learning (Aliyyah et al., 2020; Timmons et al., 2021). Table 1 provides further information on the impacts discussed above and the implications.

4 Impacts of COVID-19 on secondary education

For secondary education, most studies are survey-based but students, particularly, senior high school students could be better involved in the surveys compared to primary school students as they are sufficiently mature to provide their consents and responses to the surveys. Similarly, there are studies employing mathematical modeling of learning gain or loss. Besides, there are narrative reviews of educational impacts and policy in relation to COVID-19. Figure 3 shows a list of impacts encountered by secondary education in the COVID-19 era.

Learning projections revealed less learning among students and learning loss due to extended school closure, exacerbated by inequality and inequity experienced particularly by marginalized families (Fig. 3). School drop-out rates were projected to be higher (Azevedo et al., 2021; Dorn et al., 2020; Kuhfeld et al., 2020). As teaching and learning shifted online and remotely, countries such as Turkey initiated educational television channel to facilitate learning with provision of free internet, live courses, revision and support (Mahmut, 2020). However, there was a lack of critical analysis on the implementation of policy actions which is frequently complicated by factors such as availability of equipment, learning resources, connectivity, stability of internet and quality of teaching mentioned earlier. Dorn et al. (2020) pointed out that students still experienced learning loss in the US despite receiving average-quality remote learning. This implies a need to evaluate the effectiveness of policy actions. Further to this, Asanov et al. (2021) reported that only 59% of students had both internet access and computers/ tablets in Ecuador.

Unlike primary schools, there are comparatively more studies which directly probed the psychosocial well-being of secondary school students. In secondary schools, students were reported to experience symptoms related to depression, anxiety and stress, and some students even exhibited suicidal attempts and ideation (Fig. 3) (Gazmararian et al., 2021; Hou et al., 2020; Zhang et al., 2020). Certain groups of students were more susceptible to these symptoms especially the ethnic minorities, those of lower socioeconomic status and female gender (Gazmararian et al., 2021). Female students were also more affected by negative self-concept, somatization, hostility and impact of events variables (Karaman et al., 2021). Inconsistency in the prevalence of anxiety was documented with Zhang et al. (2020) revealing junior high school students more prone to extremely severe anxiety while Gazmararian et al. (2021) disclosing higher susceptibility to anxiety among higher graders.

In addition, school closure had resulted in changes in sleep pattern with delay in bed time and wake-up time and this does not necessary implicate a deterioration in sleep quality and duration for those having shorter sleep time before the pandemic (Fig. 3) (Dias et al., 2021). There were impacts of other nature ranging from cognitive,
### Table 1: Impacts and implications of COVID-19 on primary education

| Education type | Country/region | Study design                                      | Impact                                                                 | Implication                                                                 | References               |
|----------------|----------------|---------------------------------------------------|------------------------------------------------------------------------|-----------------------------------------------------------------------------|--------------------------|
| Primary        | Indonesia      | Exploratory case study involving 15 teachers and parents of two primary schools | Students-related impacts identified were lack of communication and social life, prolonged viewing of screen and greater challenge for those with special needs. Parents perceived children’s lack of discipline in online learning and the time needed to help them learn as problems besides inadequate technological skills and high internet bills. Teachers faced limitations in teaching methods, coverage of curriculum, the use of technology and coordination with colleagues. They also spent more time to develop e-resources and give feedback, leading to more screen time. They found communication with parents more intense and internet bills higher | There is an impetus for support from schools, related institutions and home | Putri et al. (2020)       |
### Table 1 (continued)

| Education type | Country/region | Study design | Impact | Implication | References |
|----------------|----------------|--------------|--------|-------------|------------|
| Primary school | Spain          | Evaluation of the effect on a 14-week teacher training program as intervention to the impacts of COVID-19 on 141 teachers randomly assigned to an experimental or control group. Teachers in the control group did not receive the training | Teachers in experimental group experienced less anxiety, skepticism, fatigue and were better able to use ICT and introduce emotional intelligence in classes | Additional workload faced by teachers should be considered. Technical resources and skills among the educational community for e-learning are crucial. Teacher training to support teachers during the pandemic proved effective | Pozo-Rico et al. (2020) |
| Primary school | Greece         | Quantitative survey among 160 teachers on online teaching and learning of science | > 60% teachers deemed ICT facilitated online science learning and they could execute their lesson plan and activities well online. < 50% of the teachers were able to create and improvise materials for online classes. < 50% of them opined they could teach effectively online and choose the right ICT tools for teaching. 42.5% of them expressed they needed training | Teacher training could help teachers overcome certain barriers in online teaching | Polydoros and Alasona, (2021) |
| Education type | Country/region | Study design                                                                 | Impact                                                                 | Implication                                                                 | References       |
|----------------|----------------|------------------------------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------|------------------|
| Primary school | New South Wales, Australia | Comparison of the academic achievement of Year 3 and 4 students from 113 schools | No significant difference was found in the progressive achievement tests in mathematics or readings between 2019 and 2020. There was a lag of 2 months learning in mathematics for Year 3 students of least advantaged schools, in contrast to 2 months of additional growth in mid-advantaged schools | There is an impetus to address the inequities between students | Gore et al. (2021) |
| Education type | Country/region | Study design | Impact | Implication | References |
|----------------|----------------|--------------|--------|-------------|------------|
| Primary school | UK             | Survey conducted on 1653 teachers in state schools | Teachers prioritized in supporting remote learning of children as well as their health and well-being. They were concerned about vulnerable students and tried to keep them in contact. Teachers of disadvantaged schools were more frequently involved in matters related to food security and ensuring learning without online access. Teachers in advantaged schools focused more on fun learning activities and family involvement in learning. Teachers of deprived schools tend to perceive significant impact of lockdown on students’ academic growth, besides theirs and their parents’ well-being. There was concern of students not doing school work at home, especially the disadvantaged ones | There was plan to focus on students’ psychological well-being in a safe environment. The government intends to provide internet access to more students for online learning. Online learning can only be successful when certain needs and support are met for disadvantaged families. Teaching and learning need to be engaging, motivating and considerate of parental activities. Priority should be given to reengaging students with school routines and helping them to socialize | Moss et al. (2020) |
| Education type                   | Country/region | Study design                                                                 | Impact                                                                                                                                                                                                 | Implication                                                                                           | References                      |
|---------------------------------|----------------|------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|---------------------------------|
| Primary and secondary schools   | UK             | Surveys of household members and schooling, responded by parents. The response rate was 42% | One month after the initiation of lockdown, primary school students spent averagely 2.4 h daily on schoolwork (with an average 2.2 offline lessons and 0.6 online lessons). They got an average 2 h of support from adults daily. Secondary school students spent averagely 3 h daily on schoolwork (with an average 2.3 offline lessons and 1 online lesson). They got support from adults for averagely 0.9 h daily. Children from most advantaged families spent more time on schoolwork than those from disadvantaged families. Children from most advantaged families would have less learning loss than those from the most disadvantaged families when schools reopened | Adoption of online learning will widen inequalities between socioeconomic groups. The quality of attention is more important than the amount of support a student gets | Pensiero et al. (2020)           |
| Education type | Country/region | Study design | Impact | Implication | References |
|----------------|----------------|--------------|--------|-------------|------------|
| Primary        | Indonesia      | Surveys and semi-structured interviews administered among 68 teachers on online learning called School from Home | Educational videos downloaded from online video sharing platforms were most frequently used. Social media was used to deliver learning materials. Quick and easy instructional methods were adopted due to poor connectivity. Instructional time became shorter for online learning. Administering cognitive and affective assessment was difficult due to parents’ intervention. Engaging students was challenging. Some parents had low internet literacy and financial concerns. | There is a need to involve various stakeholders in setting online learning goals aligning with national curricula based on humanism. Technological readiness needs to be addressed. Teaching materials should meet the needs of students. Instruction should be tailored to boost students’ participation. Teachers should be trained on the use of technology. | Aliyyah et al. (2020) |
| Education type        | Country/region  | Study design                                                                 | Impact                                                                                                                                                                                                 | Implication                                                                                                                                                                                                                                                                  | References                |
|-----------------------|-----------------|------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| Early primary (K2)    | Ontario Canada  | Semi-structured interviews with 25 K2 teachers and 11 parents                | Concerns were raised on inequitable access to technology and a lack of essential resources, causing widening of learning gaps. Parents found remote learning time-consuming. Parents were worried about the quality of teaching, a lack of support as well as the negative social and emotional impacts of remote learning on students. The views on synchronous and asynchronous learning were polarized | Provision of home packages, differentiated practices and additional supports is advocated. Training for families and students on the use of technology is deemed useful. A blend of synchronous and asynchronous teaching is suggested. Equity, diversity and inclusion should be considered | Timmons et al. (2021)     |
| Primary and secondary | Switzerland     | Modeling of mathematics and language performances of 28,685 students with second-order piecewise latent growth models for two periods—8 weeks of school closure and 8 weeks before school closure | Learning gains of secondary school students were not significantly affected by school closure. Learning of primary school students dampened with larger interindividual variance in learning gains | Remote learning is an effective substitute for in-class learning but it also unveils inequities among these students                                                                 | Tomasik et al. (2021)     |
| Education type          | Country/region | Study design                                           | Impact                                                                 | Implication                                                                 | References                  |
|-------------------------|----------------|--------------------------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------------------------|-----------------------------|
| Pre-primary and primary | Greece         | Online survey with 482 responses gathered from parents | Students practiced the protective measures against COVID-19 quickly. School closure affected physical activity, psychological well-being, academic performance, eating habits and quality of sleep of the students besides their families' incomes. There was an increase in web use | The need to monitor the affected areas mentioned over the long term has been raised. COVID-19 mitigation measures with effectiveness and societal impact in mind is promulgated | Siachpazidou et al. (2021) |
emotional, physiological, physical and relational on secondary school students (Karaman et al., 2021). Together with technological and educational challenges, many of these impacts, particularly psychological, physiological and physical were similar to those experienced by primary school students (Siachpazidou et al., 2021). Surveys among teachers showed that their depression and stress could determine satisfaction of secondary online teaching. Their coping, locus and self-efficacy were the protective factors in their experience of online teaching (Truzoli et al., 2021).

In relation to the impacts above, it has been suggested that resilience and positive coping are beneficial to buffer against symptoms of depression, anxiety and stress while learning loss could be mitigated through parental and teachers’ support (Kuhfeld et al., 2020; Zhang et al., 2020). The concerns of impacts worsened by inequities and inequalities are resonated here, particularly for the disadvantaged groups such as female students with poor academic performance, isolated children, low-income families, indigenous and disabled groups, as well as vulnerable groups (Fig. 3) (Asanov et al., 2021; Azevedo et al., 2021; Dorn et al., 2020; Gazmararian et al., 2021; Hou et al., 2020). There was almost a consensus that these groups require intervention, attention, support, psychosocial services and monitoring. Effective instruction and remote learning, flexible staffing and rapid catch-up period are some suggestions provided (Azevedo et al., 2021; Dorn et al., 2020). Truzoli et al. (2021) underscored the need of educational support and crisis psychology services for teachers. It seems that there is an obvious lack of studies examining the impacts of COVID-19 on secondary school teachers and it would be interesting to compare if they experienced similar impacts as primary school teachers. Table 2 provides further information on the impacts discussed above and the implications.

![Fig. 3 The impacts of COVID-19 on secondary education identified from the papers reviewed (n = 11)](image-url)
| Education type                          | Country/region | Study design                                                                 | Impact                                                                 | Implication                                                                 | References            |
|----------------------------------------|----------------|------------------------------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------|-----------------------|
| Junior high school and high school     | China          | Online survey on psychological impact among 1025 students                   | The students experienced moderate depressive, anxiety and stress symptoms mostly. Significant proportion of junior high school students had severe to extremely severe anxiety symptoms. 20.5% of junior high school students and 22.7% of high school students reported trauma-related distress | Resilience and positive coping are beneficial against depressive, anxiety and stress symptoms in the students. Positive coping seems to buffer junior high school students from trauma-related distress | Zhang et al. (2020)   |
| K12 (primary and secondary)            | US             | Projections of learning loss related to COVID-19 based on summer learning loss estimates and estimates from absenteeism research | Lower students’ learning was projected in all COVID-19 scenarios compared to a normal school year. Students were projected to also lose more of their learning gains due to extended school closure, especially those who did not receive remote instruction | Accessibility to parental and teachers’ support when schools are closed determines learning loss. Learning loss could be compensated when students return to school but COVID-19 produces uncertainties in the regain, which is complicated by inequalities | Kuhfeld et al. (2020)  |
| Senior high school                     | China          | Survey among 15 classes from 5 senior high schools in rural China, with 859 responses collected | 71.5%, 54.5% and 85.5% of the students showed symptoms of depression, anxiety and post-traumatic stress disorder respectively. 7.5% and 31.3% of them perceived suicidal attempts and suicidal ideation respectively | Female students with poor academic performance were prone to severe depression and anxiety while isolated children were prone to severe depression. These groups require attention and intervention. Exercising is beneficial for mental well-being | Hou et al. (2020)     |
| Education type          | Country/region | Study design                                                                 | Impact                                                                                                                                                                                                 | Implication                                                                                                                                                                                                 | References          |
|------------------------|----------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| Primary and secondary  | 174 countries  | Simulations using Learning Adjusted Years of Schooling measure and expected learning losses at early secondary | School closures due to COVID-19 could lead to a 0.3 to 1.1 years of schooling loss. Approximately 11 million primary and secondary school students could drop out because of financial problems. More severe exclusion and inequality were projected. Learning losses due to 5 months of school closure equated to $10 trillion | Marginalized, indigenous and disabled groups could be affected more. Coping strategies include more effective remote learning, rapid catch-up period for learning losses, addressing school safety concerns, finances of the poor and challenges of the marginalized | Azevedo et al. (2021) |
| High school            | Italy          | Online survey on teachers’ experience of online teaching. 107 responses were collected | Satisfaction of online teaching could be largely predicted by depression and stress. Protective factors included coping, locus of control and self-efficacy. 62.6% of the teachers were satisfied and fairly satisfied with online teaching | Provision of high-quality educational support as well as services focusing on crisis psychology to teachers is recommended | Truzoli et al. (2021)  |
| Education type | Country/region | Study design | Impact | Implication | References |
|----------------|----------------|--------------|--------|-------------|------------|
| High school    | Brazil         | Longitudinal surveys among 94 students concerning their sleep habits and quality | Students reported delay in bedtime by 1.5 h and wake-up time by 2 h. Chronotype was inclined to evening. For students with shorter sleep time before the pandemic, there was improvement in sleep duration and quality. Physical and psychological aspects of life deteriorated | Certain experiences of high school students during the pandemic are contradictory | Dias et al. (2021) |
| High school    | US             | Cross-sectional online survey among 9th-12th grades students of a semi-rural high school. 761 responses were collected | About a quarter of the students were extremely or very worried about the pandemic, especially those of ethnic minorities, lower socioeconomic status, higher grades and of the female gender. Female and higher grades students were more susceptible to stress, anxiety, depression and loneliness. Students of color and low socioeconomic status faced greater mental health challenges | Monitoring the mental health consequences of COVID-19 on vulnerable populations and supporting them are crucial. Measures to ensure the quantity and quality of social interactions are advocated. Grade-specific support could be advantageous | Gazmararian et al. (2021) |
| Education type                | Country/region | Study design                                      | Impact                                                                                                                                                                                                 | Implication                                                                                     | References                  |
|------------------------------|----------------|--------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------------------------|
| Primary, middle and secondary schools | Turkey         | Narrative review of educational policy actions  | Courses were delivered through Educational Informatics Network and national television channel. The Ministry of National Education provided free internet to students and live courses to 8<sup>th</sup> graders and 12<sup>th</sup> graders. Revisions for high school entrance examination were provided. Supports were given for teachers' development as well as students' and parents' well-being | Not provided as it is a narration of the policy actions                                       | Mahmut, (2020)               |
| High school                  | US             | Statistical models based on studies related to effectiveness of distance learning | Students were projected to experience significant learning loss, even those receiving average-quality remote learning. Learning loss were likely to be more among black and Hispanic students and those from low-income families. High school dropout rates would increase. Loss of learning could result in loss of earning | Timely intervention to support vulnerable students is important. Schools should promote continuous learning over summer. There is a need for more effective instruction for online learning. Flexible staffing models are suggested for a mix of remote and in-class learning | Dorn et al. (2020)            |
| Education type | Country/region  | Study design                                                                 | Impact                                                                                                                                                                                                 | Implication                                                                                                                                   | References                  |
|----------------|----------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| High school    | Turkey         | Quantitative survey among 549 students on psychological symptoms and qualitative interviews with 5 school counselors and 5 students from different schools | A total of 107 students showed severe symptoms linked to impact of events. Female students reported greater anxiety, depression, negative self-concept, somatization, hostility and impact of events variables. Students mainly experienced educational, cognitive, emotional, physiological, relational and technological difficulties during COVID-19 outbreak | School counselors could initiate online intervention programs which introduce mindful self-regulation and emotional regulation techniques such as dialectical behavior therapy. Online training of social skills can also be provided to adolescents | Karaman et al. (2021)       |
| High school    | Ecuador        | Rapid response phone survey of 1500 students                                | Fifty-nine percent of the students had internet access and computers/tablets. Seventy-four percent of the students participated in online or telelearning. Education was the daily routine of most students. The students reported problems with school closure and social isolation. Sixteen of them had symptoms of depression while the rest were happy | Students from low-income families were more prevalent among those not engaged in any schooling. Psychosocial support services are recommended | Asanov et al. (2021)        |
5 Impacts of COVID-19 on tertiary education

As with secondary education, most studies on the impacts of COVID-19 on tertiary education also took on a quantitative approach involving predominantly cross-sectional surveys and to a lesser extent, longitudinal surveys. There are comparatively more studies employing more diverse qualitative approaches such as content analysis, phenomenology, reflection, thematic analysis and narrative review. There are less restrictions in relation to research ethics for involvement of university and college students in surveys, compared to primary school and junior secondary school students. Due to a wide range of disciplines offered by higher learning institutions, many of these studies are discipline-specific. In terms of learning, there are relatively more studies examining the disruption to learning resulted from COVID-19 lockdown. Figure 4 shows a list of impacts faced by tertiary education and the number of studies reviewed which discussed the impacts.

For medicine and dentistry, clinical rotations were suspended, medical licensing exams were interrupted and applications for specialty and residency became uncertain (Fig. 4) (Rolak et al., 2020; Spanemberg et al., 2020). This aligns with stressors of rotations or residencies affecting fourth-year medical students in the US reported by Guo et al. (2021). Learning shifted to the virtual environment and this could be challenging to ensure competency of students (Deery, 2020; Spanemberg et al., 2020). Nursing students also faced the same challenges for clinical practice (Table 3) (Carolan et al., 2020). COVID-19 lockdown did not seem to affect the specialty choice of medical students in the US but reducing their exposure to urology which affirms the concern for competency (Deery, 2020; Hanson et al., 2020).

In Indonesia, Irawan et al. (2020) found students to have already felt the boredom two weeks into online learning and the assignment loads increased. Doubts on the effectiveness of these assignments affected the mood of the students. Inequity was observed in that there was greater worry among students of low-income families on internet access for online learning (Fig. 4) (Irawan et al., 2020). Having surveyed 30,383 students in 62 countries,
| Education type | Country/region       | Study design                                                                 | Impact                                                                                                                                                                                                 | Implication                                                                                                                                                                                                 | References                        |
|----------------|----------------------|------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| Medical        | US                   | Survey among 238 medical students intending to undergo urology residencies   | Specialty choice was not deterred but exposure to urology decreased. Disruption to rotations was reported                                                                                           | Virtual interactions, small group and individual communication with residents and channels to learn about hospital facilities were recommended                                                                 | Hanson et al. (2020)              |
| Management     | Singapore and Australia | Authors’ reflection                                                       | There were concerns and anxiety among students. Challenges in internships, tours and exchanges were encountered. Adapting assessment to meet accreditation requirements was a challenge to academics | Innovations in timetabling and processes, deployment of new technologies for teaching and learning and designing alternative learning support and assessment were executed. Flexible and resilient models of education were suggested | Brammer and Clark, (2020)         |
| Tourism        | Different parts of the world | Qualitative study with thematic analysis of 22 responses gathered from educators | There were insufficient practical sessions, placement pressure and low level of students’ participation. Uncertain career prospects deterred students’ recruitment | Redesign of curriculum and collaboration with industrial stakeholders and government were suggested. Digital advancement and skills in tourism education is crucial                                                      | Tiwari et al. (2020)              |
Table 3 (continued)

| Education type          | Country/region          | Study design          | Impact                                                                 | Implication                                                                 | References                  |
|-------------------------|-------------------------|-----------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------|------------------------------|
| Nursing                 | UK, Australia, US       | Review and reflection | Concerns on contracting COVID-19 arose, causing distress. Fulfilling clinical practice requirement was challenging | Virtual simulation contributing to clinical hours has been implemented. There has been a shift toward online student-centered learning. Parallel delivery of theory and practice has been initiated | Carolan et al. (2020)       |
| Dental education        | US                      | Narrative review      | Clinical teaching was suspended with implementation of stay-at-home policies. Challenges were faced in ensuring competency of students due to affected teaching, experience and assessment | Technology has been adopted with didactic distance learning. 'Off the shelf' programs for teaching and assessment are available. Sharing of materials is a viable solution to time-consuming content development | Deery, (2020)               |
| Higher education in general | 62 countries           | Survey among 30,383 students | Students were satisfied with the support from academics and universities. Lacking of computer skills and perceived higher workload are barriers to self-perceived improvement. Concerns on future career and studies, anxiety, boredom and frustration were identified | Collaboration between public and higher education authorities is crucial and attention should be given to vulnerable students | Aristovnik et al. (2020)    |
**Table 3** (continued)

| Education type                         | Country/region | Study design                      | Impact                                                                                                                                                                                                 | Implication                                                                                                                                                                                                 | References       |
|----------------------------------------|----------------|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| Private higher education in general    | Ethiopia       | Mixed methods comprising diary and survey questionnaires | Sources of income and employees’ productivity declined, which adversely affected institutional revenues | Timely interventions such as tax exemptions, loans, rent reduction, financial support, help with online platform are beneficial | Tamrat, (2021)    |
| University in general                  | US             | Questionnaire surveys on 7 universities | Higher levels of psychological impact could be anticipated among women with fair/good general health status, aged 18 to 24, spending 8 h or more on screens daily and are acquainted with someone infected with COVID-19 | The efforts to identify and address mental health among college students need to be scaled up | Browning et al. (2021) |
| Medicine                               | US             | Narrative review                   | Clinical rotations were suspended and there were uncertainties in career/specialty and residency application. Schools rolled out innovative curricula. Medical Licensing Exams were interrupted | The future directions comprise trainings in telemedicine, resumption of clinical rotations safely with PPE, voluntary assistance to physicians with childcare and other needs, and involvement in less risky clinical tasks under supervision | Rolak et al. (2020) |
| Education type             | Country/region    | Study design                          | Impact                                                                                                                                   | Implication                                                                                                                  | References                        |
|----------------------------|-------------------|---------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| Dentistry                  | Brazil            | Narrative review                      | There was a shift from classroom to remote classes using ICT platforms, with virtual teacher-student contact. Laboratory and clinical were suspended. Psychological distress among students increased | Low accessibility of ICT by low-income population is a barrier. Small-group discussion on interdisciplinary clinical cases could be helpful. Adaptation of training materials for remote learning is a need. Virtual reality is an option for clinical simulation | Spanemberg et al. (2020)          |
| Master of applied indigenous knowledge program | New Zealand       | Qualitative study with thematic analysis of 36 responses gathered from students | Workload increased with greater challenges to juggle different responsibilities. Financial struggles were more prevalent. Feelings of anxiety, depression, stress and loneliness emerged. Delayed progress in learning and impacts on quality of work was experienced. Online teaching and learning and academic support were provided | Being flexible, rendering greater support to students and being student-centered are important | Rangiwai et al. (2020)           |
| Education type                  | Country/region | Study design                                                                 | Impact                                                                                                                                                                                                 | Implication                                                                                                                                  | References          |
|--------------------------------|----------------|------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| Higher education in general    | Australia      | Reflection on the equitable participation among migrant or refugee students | Challenges in providing students access to infrastructure for online learning arose. Loss of employment and income deepened socioeconomic concern. Financial hardship affected ability to access equipment and internet for learning | The pandemic presents opportunities for equity policy reform, funding and practice which should be approached from the viewpoints of the migrant/refugee students | Mupenzi et al. (2020) |
| Medicine                       | US             | Nationwide online survey on 852 undergraduate medical students                | Highest stress was reported by the second- to fourth-year students, particularly those with preexisting mental health conditions. The highest stressor of first- and second-year students was trust in government institution. For third-year students, it was delay/availability of standardized exams. For fourth-year students, it was rotations/residencies | Identifying the psychological impacts of COVID-19 helps to improve the well-being of medical students. It helps increasing educational preparedness to future crisis | Guo et al. (2021)   |
| Education type         | Country/region | Study design                                      | Impact                                                                                     | Implication                                      | References                  |
|------------------------|----------------|---------------------------------------------------|---------------------------------------------------------------------------------------------|--------------------------------------------------|-----------------------------|
| University abroad      | Hong Kong      | Online questionnaire survey among 124 students studying in the UK or US | Students who stayed back experienced higher stress linked to COVID-19 than those who returned home. They also reported higher perceived stress and severe insomnia. Stressors comprised academics, health, available of reliable information about COVID-19 and lack of social support. | A greater support is advocated for international students who stayed back at their universities during the pandemic | Lai et al. (2020)            |
| Undergraduate forestry | Greek          | Online questionnaires among 181 students          | Concern and anger were felt by students during lockdown. Female students experienced greater fear, panic and despair than male students. | Mental health of students requires frequent monitoring. Psychological counseling on anxiety and fear could be provided. Training on remote learning could be beneficial. | Karasmanaki and Tsantopoulos, (2021) |
| University generally   | Indonesia      | Phenomenology with telephone interviews of 30 subjects | Students got bored of online learning after the first two weeks of its implementation. Students of low-income families tended to worry about internet access for online learning. High loads of assignment considered ineffective by students caused mood changes. | Psychological and social supports are necessary. | Irawan et al. (2020)        |
Table 3 (continued)

| Education type                                                                 | Country/region | Study design                                                                 | Impact                                                                                                                                                                                                                                                                                                                                 | Implication                                                                                                                                                                                                 | References       |
|--------------------------------------------------------------------------------|----------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| Applied and basic biological, environmental and geophysical science             | US             | Online survey responses gathered from 117 instructors                          | Instructing courses with field components was impacted. Plans were made to reduce field learning outcomes and change them to remote teaching in the field. Experience was identified as the greatest field teaching barrier while technology was the greatest remote teaching barrier. There was potential intensification of inequalities between students due to distance learning modalities. | Employment of student-centered, more active approaches is proposed, together with institutional support and thoughtful remote course design | Barton, (2020)    |
| Universities in general                                                        | Australia      | Analysis of the contents of annual reports of all Victorian public universities with application of Laughlin’s Habermasian insights of change | The disclosed risk of COVID-19 was minimal. There was significant income loss reported and numerous typical cost-cutting strategies were proposed, including retrenchment.                                                                                                                                                     | Focusing on growth could risk financial viability and quality of teaching and research. There is a need to improve external risk disclosures of the universities.                                                  | Carnegie et al. (2021) |
| Education type | Country/region | Study design | Impact | Implication | References |
|----------------|----------------|--------------|--------|-------------|------------|
| Urban university | US | Longitudinal study among 86 freshmen | Students with parents having low educational level perceived more stress and subjective well-being as well as financial and academic impacts. They were not more resilient than those whose parents received higher education. Grit was correlated to greater pandemic resilience and lower psychological impact. Gratitude was linked to lower academic impact | Grit and gratitude could be beneficial to students’ subjective well-being and their ability to cope with the impacts of COVID-19 | Bono et al. (2020) |
| University | Spain | Online survey responded by 2530 members (students and employees) of the University of Valladolid | 21.34%, 34.19% and 28.14% of the respondents perceived moderate to extreme anxiety, depression and stress respectively, with students from Arts & Humanities and Social Sciences & Law perceiving more severe signs. Staff had lower scores in the measures than students | Careful monitoring of the mental health of students and employees is recommended. Adaptive psychological services could be useful | Odriozola-González et al. (2020) |
Aristovnik et al. (2020) also revealed higher assignment load among students and their lack of computer skills could hamper their improvement though they were generally satisfied with the support rendered by academics and universities. Besides, workload increase was experienced by students in New Zealand having to juggle different responsibilities and there was growing concern of financial stability (Table 3) (Rangiwai et al., 2020). In particular to migrant or refugee students, inequity and inequality in terms of infrastructural access to online learning were apparent as income stability was shaken (Mupenzi et al., 2020).

For science courses placing high weights on experiential leaning such as applied and basic biological, environmental and geophysical science, the field components were disrupted and there were plans among instructors to reduce field learning outcomes while moving them to remote teaching but this had the drawbacks of depriving students of fieldwork experience and teachers might not be technologically prepared. Remote learning could also widen the inequalities between students (Fig. 4) (Barton, 2020). Educators of tourism also raised concern on practical and placement. As tourism was badly impacted, uncertain career prospects deterred students’ recruitment (Tiwari et al., 2020). Similarly, there was concern for internships, tours and exchanges among management educators who also mentioned the challenges to adapt assessment to meet accreditation requirements (Fig. 4) (Brammer & Clark, 2020).

Universities as a whole were cautious in the disclosure of COVID-19 risk. Significant revenue loss was reported by universities in Australia, sparking proposal of strategies to cut cost such as staff retrenchment (Carnegie et al., 2021). In Ethiopia, Tamrat (2021) revealed that the sources of income and productivity of employees in private higher education declined, leading to negative impacts on institutional revenues. It seems that higher learning institution could consider taking care of the income and productivity of employees as a channel for increasing revenue, instead of focusing on retrenchment (Carnegie et al., 2021; Tamrat, 2021).

There were numerous studies examining the psychological impacts experienced by students in higher learning institutions (Fig. 4). Students of different disciplines generally felt anxiety, depression, stress and loneliness (Guo et al., 2021; Rangiwai et al., 2020). Guo et al. (2021) differentiated the stressors of medical students of different years and found first- and second-year students were affected by trust in government institution and third-year students affected by delay/availability of standardized exams. Lai et al. (2020) revealed higher perceived stress and severe insomnia among Hong Kong students studying abroad who stayed back during COVID-19 restrictions. In Greek, concern and anger were felt by students with female students experiencing greater fear, panic and despair than male students (Karasmanaki & Tsantopoulos, 2021). This is parallel to the findings of Browning et al. (2021) shedding light to higher psychological impact among women aged 18 to 24. Odriozola-González et al. (2020) demonstrated potential connection between disciplines of study and psychological state where they reported students from Arts & Humanities and Social Sciences & Law perceived more severe signs of anxiety, depression and stress. Psychological state is also affected by inequity whereby greater stress, subjective well-being, financial and academic impacts were perceived by students with parents having low educational level (Bono et al., 2020).

These studies point to a need to enhance virtual interaction especially for medicine and nursing via small group discussion, individual interaction with residents, exposure to hospital facilities, simulation of clinical practices and trainings in telemedicine (Carolan et al., 2020; Deery, 2020; Hanson et al., 2020; Rolak et al., 2020; Spanemberg et al., 2020). Parallel delivery of theory and practice and sharing of materials to offset time-consuming
development of online learning contents are deemed helpful for these students (Carolan et al., 2020; Deery, 2020). When clinical rotations are resumed, safety should be prioritized (Rolak et al., 2020). Generally, there is a call for student-centered learning, redesign of curriculum innovations such as in timetabling, deployment of new technologies for online teaching and learning, and collaboration of multiple parties particularly in addressing inequities and inequalities (Aristovnik et al., 2020; Barton, 2020; Brammer & Clark, 2020; Tiwari et al., 2020). There are opportunities for policy reform, funding and practice which cater for migrant/refugee students (Mupenzi et al., 2020). There is a need to improve external risk disclosures, as well as to sustain financial viability and quality of teaching and research by not overemphasizing the growth of institutions (Carnegie et al., 2021). Interventions such as tax exemptions, financial support and rent reduction would help in addressing keeping employees’ productive and financially secured (Tamrat, 2021). In terms of mental health, measures similar to primary and secondary students such as monitoring, support and psychological services are highlighted, especially for international students, migrant/refugee students (Lai et al., 2020; Mupenzi et al., 2020; Odriozola-González et al., 2020). Cultivating grit and gratitude among students could help with their well-being and coping ability (Bono et al., 2020). Table 3 provides further information on the impacts discussed above and the implications.

6 Recommendations for future educational practices

Currently, different countries are at different stages of combating COVID-19 with some countries in partial lockdown and others easing lockdown and travel restrictions. With progressive vaccination, there is hope that schools could reopen. However, there is much uncertainty hovering over education which now becomes dependent on the severity of COVID-19 complicated by the emergence of new virus variants. Possibilities remain that schools may need to be closed anytime intermittently after they resume operations and full implementation of protective measures is crucial when schools open. The future education could consider the following features:

1. Adaptability—Curricula need to be adaptive to the unpredictable switches between physical classes and online learning with cycles of school opening and closing, and this has also been advocated by Timmons et al. (2021) who proposed combining synchronous and asynchronous teaching. Curricula with alternative components of independent and online learning could be beneficial to learners to explore the new contents taught on their own through online or other modalities. For instance, additional instruction could be provided to direct learners in exploring certain concepts themselves, after which educators only need to check the progress made. Assessment has been adapted to facilitate accreditation and training materials have been modified to suit remote learning (Brammer & Clark, 2020; Spanemberg et al., 2020). This aligns with student-centered learning suggested by multiple scholars (Barton, 2020; Rangiwai et al., 2020).

2. Diverse learning modalities and concurrence of the modalities—More learning modalities could be explored (Spanemberg et al., 2020). Higher learning institutions have already offered fully online courses and blended learning to cater for different learners (Cahapay, 2020). This can be extended to senior high school students. However, for students opting for on-campus learning upon enrollment, a total shift to online learning could deprive them of the learning experiences they long for. It is crucial to check with
these students on their preferences for learning modalities. Studies have underscored that students could get bored of online learning and online learning does not provide comparable face-to-face experience (Aristovnik et al., 2020; Irawan et al., 2020). They are nostalgic of and yearn to resume face-to-face learning (Kundu & Bej, 2021). Where possible, face-to-face learning for these students and merging of face-to-face with online audiences could be considered.

3. Flexible staffing and learning model—With possible alternation or concurrence of face-to-face and online learning, sometimes in the same space, flexible staffing model needs to be considered with potential recruitment of casual educators to fill in the manpower for concurrent implementation of multiple learning modalities and a smooth switch from working from home to working in schools (Brammer & Clark, 2020; Dorn et al., 2020). Flexible learning models comprising blended learning with thoughtful proportions of face-to-face and online learning, fully online learning for independent learners and an option of face-to-face or online learning by offering physical classes to both online and face-to-face audiences could be offered (Timmons et al., 2021). The concurrence of online and face-to-face learning is frequently translated to higher workload for teachers due to the need to prepare different materials suited to the different learning modes. In view of this, some higher learning institutions have offered lecturers the flexibility to determine the proportions of teaching, research and services they are comfortable with or increased teaching-focused positions with minimal research component (Miller, 2019).

4. Interactive, responsive and authentic virtual learning experience—If online learning were to continue, students are desirous of online learning experience that is engaging, interactive and responsive in the sense that they could actively participate in learning and get responses and feedback timely if not quickly (Cahapay, 2020; Moss et al., 2020). Authentic virtual learning is important for experiential learning involving fieldwork, clinicals, practical, etc. Such experience has been stressed in medical education with measures such as telemedicine visits, virtual meetings, small-group virtual case studies (Hanson et al., 2020; Shah et al., 2020). Besides, the incorporation of social affordances, for instance, through social-learning plugins of online learning platforms could be beneficial in creating a sociable and more gratifying learning environment (Weidlich & Bastiaens, 2019).

5. Addressing inequities and inequalities—With cycles of school opening and closing possible, it is important to pay attention to students from less advantaged families, migrant/refugee students, female students, vulnerable students and disabled students in terms of their accessibility to internet, learning resources and support (Azevedo et al., 2021; Gazmararian et al., 2021; Moss et al., 2020; Mupenzi et al., 2020). While teachers have endeavored to identify, monitor and support the vulnerable groups, policy-makers need to ensure their financial, technological and learning needs are addressed in the COVID-19 era. Infrastructural and resource development to improve inequalities is as important (Mupenzi et al., 2020; Timmons et al., 2021). Infrastructural and resource inequality between developing and developed countries is worth noting where a lack of stable network connectivity is more prevalent in developing countries and many rural areas in those countries are without network, making online teaching and learning especially challenging (Chavez et al., 2015). Improving connectivity in developing countries may be affected by a nexus of social, economic and governance factors which prompts government plans and financial allocation, subsidies, price control and other market-based approaches (Bhandari, 2020). Technologically, the use of TV White Space (TVWS) internet connection has been proposed to improve rural connectivity (Chavez et al., 2020).
et al., 2015). At national level, there is a need for strategic planning and budget allocation for improving connectivity, in addition to market-based instruments through tax exemptions and subsidies for expenses related to information technology (Bhandari, 2020). At institutional level, budget cuts were common due to the economic impacts of COVID-19 but maintenance and enhancement of the existing infrastructure is necessary to accommodate the shift to online teaching and learning. Despite, supply or loan of digital learning devices and financial support to underprivileged students should receive proportionate attention. Exemptions of loan fees temporarily or conditionally, and reducing the fees of short online courses could also be considered (Sá & Serpa, 2020).

6. Support—As COVID-19 lockdown is taking a toll on the social and psychological well-being of educators and learners, education in the COVID-19 era should incorporate psychosocial support to address their psychological and social need. Studies have suggested counseling and periodic social interactions (Gazmararian et al., 2021; Karaman et al., 2021; Karasmanaki & Tsantopoulos, 2021). However, there is a risk of overstraining school counselors. Decentralization of counseling services to involve educators in identifying and monitoring students at risk of psychosocial problems before referring them to counselors has been proposed (Karasmanaki & Tsantopoulos, 2021). There is also a need for support in using technology in teaching and learning via training (Polydoros & Alasona, 2021; Pozo-Rico et al., 2020). There are also instances of providing additional consultation and psychosocial support through social media particularly for individuals who require personal attention (Mukhtar et al., 2020).

7. Innovation with simplification and standardization—The switch to remote learning has catalyzed innovation in this domain. Innovation is particularly obvious in medical education, for instance, through pre-recorded lectures, interactive online workshop and case studies as well as online quizzes (Gomez et al., 2020). While innovation in teaching and learning is an important element of remote learning, there has been complaints of too many different tools used by different educators and these tools sometimes served the same purpose (Besser et al., 2020). Within a learning institution, it would be helpful to standardize the tools used for a particular purpose to prevent cluttering the memory and screen spaces of learning gadgets (Hermanto & Srimulyani, 2021). This would help streamlining learning process and reducing the impacts of inequity and inequality.

8. Quality assurance—With learning taking on multiple modalities concurrently or non-concurrently, there is a need for countries to have more accommodating quality assurance frameworks to safeguard the quality of contents, instruction and assessment, while facilitating adaptation of teaching and learning (Brammer & Clark, 2020). For instance, assessment for psychomotor skills could be replaced with analysis and simulation using datasets provided or secondary data collected. Where data collection or generation is required, students could produce videos of the process (Gamage et al., 2020). For courses accredited by quality assurance agencies, accreditation criteria could adaptively include facets of online synchronous and asynchronous learning, particularly the quality of e-resources, the use of learning management platforms, online student feedback and student support to maintain the quality of teaching and learning in spite of the disruption (Giatman et al., 2020).
7 Conclusion

COVID-19 has given rise to educational disruption which unveils shortfalls in the preparedness of various levels of education to such crisis. Teaching and learning have continued remotely during lockdown and have alternated between face-to-face and online modalities with easing and tightening of lockdown. Remote learning has affected educators and learners in multiple ways particularly in terms of learning loss and slower learning gain among learners, limitations in instructions, assessment, and experiential learning in virtual environment, technology-related constraints, connectivity, learning resources and materials, as well as psychosocial well-being. These impacts are exacerbated by inequalities in the distribution of resources as well as inequities attributed to socioeconomic status, gender, ethnicity as well as learning ability and physical conditions. Education in the COVID-19 era also takes a toll on parents particularly of primary school children who require parental support. With COVID-19 likely to stay for some time, future education should focus on adaptability, concurrence of diverse learning modalities, flexible staffing and learning model, support, innovation with simplification and standardization as well as interactive, responsive and authentic virtual environment. This review contributes to teaching and learning in the COVID-19 era by systematically presenting and highlighting the challenges faced, implications made and providing recommendations to the future directions of education. It calls for a model of education in the COVID-19 era to increase preparedness of education at various levels and minimize the impacts resulted from unpredictability associated with changing COVID-19 situation.

Declarations

Conflict of interest No conflicts of interest have been identified.

References

Adedoyin, O. B., & Soykan, E. (2020). Covid-19 pandemic and online learning: The challenges and opportunities. Interactive Learning Environments. https://doi.org/10.1080/10494820.2020.1813180

Aliyyah, R. R., Rachmadullah, R., Samsudin, A., Syaodih, E., Nurtanto, M., & Tambunan, A. R. S. (2020). The perceptions of primary school teachers of online learning during the COVID-19 pandemic period: A case study in Indonesia. Journal of Ethnic and Cultural Studies, 7(2), 90–109.

Aristovnik, A., Keržič, D., Ravšelj, D., Tomažević, N., & Umek, L. (2020). Impacts of the COVID-19 pandemic on life of higher education students: A global perspective. Sustainability. https://doi.org/10.3390/su12208438

Asanov, I., Flores, F., McKenzie, D., Mensmann, M., & Schulte, M. (2021). Remote-learning, time-use, and mental health of Ecuadorian high-school students during the COVID-19 quarantine. World Development, 138, 105225. https://doi.org/10.1016/j.worlddev.2020.105225

Azevedo, J. P., Hasan, A., Goldemberg, D., Geven, K., & Iqbal, S. A. (2021). Simulating the potential impacts of COVID-19 school closures on schooling and learning outcomes: a set of global estimates. The World Bank Research Observer, 36(1), 1–40. https://doi.org/10.1093/wbro/lkab003

Barton, D. C. (2020). Impacts of the COVID-19 pandemic on field instruction and remote teaching alternatives: Results from a survey of instructors. Ecology and Evolution, 10(22), 12499–12507. https://doi.org/10.1002/ece3.6628

Besser, A., Flett, G. L., & Zeigler-Hill, V. (2020). Adaptability to a sudden transition to online learning during the COVID-19 pandemic: Understanding the challenges for students. Scholarship of Teaching and
Giatman, M., Siswati, S., & Basri, I. Y. (2020). Online learning quality control in the pandemic Covid-19.

Gazmararian, J., Weingart, R., Campbell, K., Cronin, T., & Ashta, J. (2021). Impact of COVID-19 pandemic on the education sector.

Gamage, K. A. A., Wijesuriya, D. I., Ekanayake, S. Y., Rennie, A. E. W., Lambert, C. G., & Gunawardhana, K. H. D. T. (2020). Rethinking education in the new normal post-COVID-19 era: A curriculum studies perspective.

Fairlie, R. & Fossen, F. M. (2021). The early impacts of the COVID-19 pandemic on business sales.

Fana, M., Torrejón Pérez, S., & Fernández-Macías, E. (2020). Employment impact of COVID-19 crisis: From short term effects to long term prospects.

Fama, M., Torrejón Pérez, S., & Fernández-Macías, E. (2020). Employment impact of COVID-19 crisis: From short term effects to long term prospects.

Fearns, M., Ho, Y., & Read, C. (2020). COVID-19 pandemic impact on sleep habits, chronotype, and health-related quality of life among high school students: A longitudinal study.

Fernandez, J., & Varela, S. (2020). Psychological distress, anxiety, family violence, suicidality, and wellbeing in New Zealand during the COVID-19 pandemic: Can grit and gratitude help?

Fernández-Macías, E., & Bokde, V. (2020). Possible impacts of COVID-19 pandemic and lockdown on education sector in India.

Fernández-Macías, E., & Bokde, V. (2020). Possible impacts of COVID-19 pandemic and lockdown on education sector in India.

Fernández-Macías, E., & Bokde, V. (2020). Possible impacts of COVID-19 pandemic and lockdown on education sector in India.

Fernández-Macías, E., & Bokde, V. (2020). Possible impacts of COVID-19 pandemic and lockdown on education sector in India.

Fernández-Macías, E., & Bokde, V. (2020). Possible impacts of COVID-19 pandemic and lockdown on education sector in India.
Gore, J., Fray, L., Miller, A., Harris, J., & Taggart, W. (2021). The impact of COVID-19 on student learning in New South Wales primary schools: An empirical study. *The Australian Educational Researcher*. https://doi.org/10.1007/s13834-021-00436-w

Guo, A. A., Crum, M. A., & Fowler, L. A. (2021). Assessing the psychological impacts of COVID-19 in undergraduate medical students. *International Journal of Environmental Research and Public Health*. https://doi.org/10.3390/ijerph18062952

Hanson, K. A., Borofsky, M. S., Hampson, L. A., Breyer, B. N., Kern, N. G., Conti, S. L., Sorensen, M. D. (2020). Capturing the perspective of prospective urology applicants: Impacts of COVID-19 on medical education. *Urology*, 146, 36–42. https://doi.org/10.1016/j.urolology.2020.09.027

Hermanto, Y. B., & Srimulyani, V. A. (2021). The challenges of online learning during the Covid-19 pandemic. *Jurnal Pendidikan Dan Pengajaran*, 54(1), 46–57. https://doi.org/10.23887/jpp.v54i1.29703

Hou, T.-Y., Mao, X.-F., Dong, W., Cai, W.-P., & Deng, G.-H. (2020). Prevalence of and factors associated with mental health problems and suicidality among senior high school students in rural China during the COVID-19 outbreak. *Asian Journal of Psychiatry*, 54, 102305. https://doi.org/10.1016/j.ajp.2020.102305

Irawan, A. W., Dwisona, D., & Lestari, M. (2020). Psychological impacts of students on online learning during the pandemic COVID-19. *KONSELI: Journal Bimbingan Dan Konseling (E-Journal)*, 7(1), 53–60.

Karaman, M. A., Eşici, H., Tomar, İH., & Aliyev, R. (2021). COVID-19: Are school counseling services ready? Students’ psychological symptoms, school counselors’ views, and solutions. *Frontiers in Psychology*, 12, 647740. https://doi.org/10.3389/fpsyg.2021.647740

Karadumanaki, E., & Tsantopoulos, G. (2021). Impacts of social distancing during COVID-19 pandemic on the daily life of forestry students. *Children and Youth Services Review*, 120, 105781. https://doi.org/10.1016/j.childyouth.2020.105781

Kuhfeld, M., Soland, J., Tarasawa, B., Johnson, A., Ruzek, E., & Liu, J. (2020). Projecting the potential impact of COVID-19 school closures on academic achievement. *Educational Researcher*, 49(8), 549–565.

Kundu, A., & Bej, T. (2021). COVID-19 response: students’ readiness for shifting classes online. *Corporate Governance: The International Journal of Business in Society*, ahead-of-p(ahead-of-print). https://doi.org/10.1108/CG-09-2020-0377

Lai, A.Y.-K., Lee, L., Wang, M.-P., Feng, Y., Lai, T.T.-K., Ho, L.-M., & Lam, T.-H. (2020). Mental health impacts of the COVID-19 pandemic on international university students, related stressors, and coping strategies. *Frontiers in Psychiatry*, 11, 584240. https://doi.org/10.3389/fpsyt.2020.584240

Mahmut, Ö. (2020). Educational policy actions by the Ministry of National Education in the times of COVID-19 pandemic in Turkey. *Kastamonu Eğitim Dergisi*, 28(3), 1124–1129.

Miller, J. (2019). Where does the time go? An academic workload case study at an Australian university. *Journal of Higher Education Policy and Management*, 41(6), 633–645. https://doi.org/10.1080/1360080X.2019.1635328

Moss, G., Allen, R., Bradbury, A., Duncan, S., Harmey, S., & Levy, R. (2020). *Primary teachers’ experience of the COVID-19 lockdown–Eight key messages for policymakers going forward*. London, UK: UCL Institute of Education.

Mukhtar, K., Javed, K., Arooj, M., & Sethi, A. (2020). Advantages, limitations and recommendations for online learning during COVID-19 pandemic era. *Pakistan Journal of Medical Sciences*, 36(COVID19-S4), S27–S31. https://doi.org/10.12669/pjms.36.COVID19-S4.2785

Mupenzi, A., Mude, W., & Baker, S. (2020). Reflections on COVID-19 and impacts on equitable participation: The case of culturally and linguistically diverse migrant and/or refugee (CALDM/R) students in Australian higher education. *Higher Education Research & Development*, 39(7), 1337–1341. https://doi.org/10.1080/07294360.2020.1824991

Odriozola-González, P., Planchuelo-Gómez, Á., Iruitia, M. J., & de Luis-García, R. (2020). Psychological effects of the COVID-19 outbreak and lockdown among students and workers of a Spanish university. *Psychiatry Research*, 290, 113108. https://doi.org/10.1016/j.psychres.2020.113108

Our World in Data. (2021). Daily new confirmed cases of COVID-19. Retrieved from https://ourworldindata.org/grapher/daily-new-confirmed-cases-of-covid-19-positive-rate

Pensiero, N., Kelly, A., & Bokhove, C. (2020). *Learning inequalities during the Covid-19 pandemic: How families cope with home-schooling*.

Polydoros, G., & Alasona, N. (2021). Using E-Learning to teach science in Covid-19 era at primary education level. *Journal of Research and Opinion*, 8(6), 2964–2968.
Pozo-Rico, T., Gilar-Corbí, R., Izquierdo, A., & Castejón, J.-L. (2020). Teacher training can make a difference: Tools to overcome the impact of COVID-19 on primary schools. An experimental study. *International Journal of Environmental Research and Public Health*, vol. 17. https://doi.org/10.3390/ijerph17228633

Putri, R. S., Purwanto, A., Pramono, R., Ashari, M., Wijayanti, L. M., & Hyun, C. C. (2020). Impact of the COVID-19 pandemic on online home learning: An explorative study of primary schools in Indonesia. *International Journal of Advanced Science and Technology*, 29(5), 4809–4818.

Rangiwi, B., Chand, B. S.-K., & Mataroa, R. (2020). The impacts of COVID-19 on the 2020 cohort of the Master of Applied Indigenous Knowledge programme at Te Wānanga o Aotearoa in Māngere. *Te Kaharoa*, 15(1).

Rolak, S., Keefe, A. M., Davidson, E. L., Aryal, P., & Parajuli, S. (2020). Impacts and challenges of United States medical students during the COVID-19 pandemic. *World Journal of Clinical Cases*, 8(15), 3136.

Sá, M. J., & Serpa, S. (2020). The COVID-19 pandemic as an opportunity to foster the sustainable development of teaching in higher education. *Sustainability*. https://doi.org/10.3390/su12208525

Shah, S., Diwan, S., Kohan, L., Rosenblum, D., Gharibo, C., Soin, A., Provenzano, D. A. (2020). The technological impact of COVID-19 on the future of education and health care delivery. *Pain Physician*, S367–S380.

Siachpazidou, D. I., Kotsiou, O. S., Chatziparasidis, G., Papagiannis, D., Vavougios, G. D., Gogou, E., & Gourgoulianis, K. I. (2021). Action and reaction of pre-primary and primary school-age children to restrictions during COVID-19 pandemic in Greece. *Journal of Personalized Medicine*. https://doi.org/10.3390/jpm11060451

Spanemberg, J. C., Simões, C. C., & Cardoso, J. A. (2020). The impacts of the COVID-19 pandemic on the teaching of dentistry in Brazil. *Journal of Dental Education*, 84(11), 1185–1187. https://doi.org/10.1002/jded.12364

Stovold, E., Beecher, D., Foxlee, R., & Noel-Storr, A. (2014). Study flow diagrams in Cochrane systematic review updates: An adapted PRISMA flow diagram. *Systematic Reviews*, 3(1), 54. https://doi.org/10.1186/2046-4053-3-54

Tamrat, W. (2021). Enduring the impacts of COVID-19: Experiences of the private higher education sector in Ethiopia. *Studies in Higher Education*, 46(1), 59–74. https://doi.org/10.1080/03075079.2020.1859690

Tang, K. H. D. (2020a). A scoping review of studies on COVID-19. *International Journal of Science and Healthcare Research*, 5(2), 205–214.

Tang, K. H. D. (2020b). Personality traits, teamwork competencies and academic performance among first-year engineering students. *Higher Education, Skills and Work-Based Learning*. https://doi.org/10.1108/HESWBL-11-2019-0153

Tang, K. H. D. (2021a). Controversies of the post-lockdown new normal: It may not be entirely normal. *Current Research Journal of Social Sciences and Humanities*, vol. 11. Retrieved from http://journalofsocialsciences.org/article/60/

Tang, K. H. D. (2021b). From movement control to national recovery plan: Malaysia’s strategy to live with COVID-19. *International Journal of Science and Healthcare Research*, 6(4), 286–292. https://doi.org/10.52403/ijshr.2021b1040

Tang, K. H. D., & Chin, B. L. F. (2021). Correlations between Control of COVID-19 Transmission and Influenza Occurrences in Malaysia. *Public Health*. https://doi.org/10.1016/j.puhe.2021.07.007

Timmons, K., Cooper, A., Bozek, E., & Braund, H. (2021). The Impacts of COVID-19 on early childhood education: Capturing the unique challenges associated with remote teaching and learning in K-2. *Early Childhood Education Journal*. https://doi.org/10.1007/s10643-021-01207-z

Tiwari, P., Séraphin, H., & Chowdhary, N. R. (2020). Impacts of COVID-19 on tourism education: Analysis and perspectives. *Journal of Teaching in Travel & Tourism*. https://doi.org/10.1080/15313220.2020.1850392

Tomasik, M. J., Helbling, L. A., & Moser, U. (2021). Educational gains of in-person vs. distance learning in primary and secondary schools: A natural experiment during the COVID-19 pandemic school closures in Switzerland. *International Journal of Psychology*, 56(4), 566–576. https://doi.org/10.1002/ijop.12728

Truzoli, R., Pirolo, V., & Conte, S. (2021). The impact of risk and protective factors on online teaching experience in high school Italian teachers during the COVID-19 pandemic. *Journal of Computer Assisted Learning*, 37(4), 940–952. https://doi.org/10.1111/jcal.12533

UNESCO. (2021). Global monitoring of school closures caused by COVID-19. Retrieved from https://en.unesco.org/covid19/educationresponse#schoolclosures
Weidlich, J., & Bastiaens, T. J. (2019). Designing sociable online learning environments and enhancing social presence: An affordance enrichment approach. *Computers & Education, 142*, 103622. https://doi.org/10.1016/j.compedu.2019.103622

Zhang, C., Ye, M., Fu, Y., Yang, M., Luo, F., Yuan, J., & Tao, Q. (2020). The psychological impact of the COVID-19 pandemic on teenagers in China. *Journal of Adolescent Health, 67*(6), 747–755. https://doi.org/10.1016/j.jadohealth.2020.08.026

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