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 SURVEY

# Technology Dependency and Impact During COVID-19: A Systematic Literature Review and Open Challenges

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**ABSTRACT** The COVID-19 pandemic is still a challenge in many countries, although life must proceed while ensuring the pandemic is managed critically. Due to the delay in producing permanent medical intervention, despite the availability of vaccines, there is still a need to depend on technology in performing several tasks. A systematic literature review that provides comprehensive evidence on technology dependence and the impact of technology on individuals during the pandemic is lacking. This study systematically reviewed scholarly works related to technology dependency from a broad view since the pandemic and mapped the research findings into a taxonomy, thus establishing the trend in technology type, major areas of technology dependency, and the impact of technology during the pandemic. The mapped taxonomy is used to expound on open challenges and recommendations. The final set from the systematic search was 76 articles. Technology might be an avenue for administering and enhancing health services, improving outreaches, and supporting curbing the spread of diseases. However, the impact of technology dependence is both positive and negative. A systematic mapping was conducted to explore the literature on the impacts of technology, where there is a need for further research. Notwithstanding the category, most of the reviewed articles emphasized the usage and impact of technology at such a time of the pandemic and provided insights on the manner of addressing them. Realistically, there has been an acceleration of digitalization trends in the present era of the COVID-19 pandemic and the possibility of rapid development of novel digital technologies.

**INDEX TERMS** COVID-19, technology, technology dependency, technology usage, pandemic, digital technologies, technology impacts.

## I. INTRODUCTION

At the latter end of 2019, the world was hit with a critical plague, known as the COVID-19 pandemic. To date, the COVID-19 pandemic is still a challenge in many countries, even though life has to move on while ensuring the pandemic is managed critically. This led to rapid change in the way of life for the general populace in various nations of the world. The COVID-19 pandemic has affected almost all

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sectors of society, such as public health, education, business, transport, entertainment, and well-being amongst others. Furthermore, public health alongside economic crises has become unprecedented across the globe [1]. Among the most crucial challenges is how life and human health can be protected while ensuring the populace carries out their daily activities and still produce maximal results. More so, the COVID-19 infectious disease spreads rapidly and has a very high mutating capability, one of which can be likened to a respiratory tract infection, thus, posing a serious health threat for persons suffering from underlying chronic diseases

such as diabetes, cardiovascular diseases, or those with the weak immune system and the elderly [2], [3]. Due to the delay in producing permanent medical intervention, despite the availability of vaccines, there is still a need to rely on the use of technology in performing several tasks, to as much as possible restrain direct physical contact. Technology dependency refers to a short or long term reliance on technological appliances and tools, such as machines as well as techniques that could be used for evaluation, satisfaction, or to resolve a particular problem, ranging from health challenges, eases of academic presentation, business transactions, transportation, amongst others [4]. Consequently, the reliance on technology by society is reaching a peak in the advent of the COVID-19 pandemic, alongside occupational and social changes [5] which might likely become a norm far after the pandemic has been contained. Thus, it is crucial to deliberate and come up with decisions that are intentional as well as mindful, tailored towards the leveraging of technology for the enhancement of lives, stress reduction, and improvement of mental health and well-being. A couple of scholarly works have been published across diverse phases of the COVID-19 pandemic. However, most of the studies concentrated on the use of technology in health/healthcare - focusing more on medical systems, education, online shopping, business, well-being, and a few on psychological and social life. Nevertheless, it is important to state that the dependency on technology and its importance in the COVID-19 era haven't been given much attention in the literature. Though there are works that have been reviewed on technology dependency during the COVID-19 era, especially at its peak, little is known as to what the post-COVID-19 periods will be like as regards the utilization and dependence on technology for various aspects of life.

Moreover, a couple of changes has been erupted by the COVID 19 pandemic which affects several areas of human lives, thus resulting to numerous challenges and opportunities surprisingly. Though some studies carried out investigation on disparities in how adoption of technology impacts daily living activities from the perspective of vulnerability [6], [7], [8], it is evident that the COVID 19 pandemic is not only responsible for variations in work and learning patterns of individuals but also in their everyday lifestyle [9]. Globally, the era of COVID 19 witnessed the initiation of various preventive measures, some of which included social/physical distancing, lockdowns, as well as the prevalence of working and schooling from home. All these preventive measures lead to vast changes in lifestyle as a lot of restrictions was placed on travel, social gatherings, resulting to a higher dependence on online shopping and lack of fitness [10]. Thus, an increased dependency on technology and changes in lifestyle was observed during the peak of the COVID 19 pandemic. Surprisingly, as the pandemic began to ease down in various countries, there seems to be a surge in the usage of digital technologies as people have now started to familiarize with technology usage in their daily life [11]. Therefore, the need to review dependency of technology

during the COVID 19 pandemic and how this affects the post COVID 19 era is of utmost importance.

Thus, this systematic review was conducted to investigate one dependency on technology as well as the impact it has made during the COVID-19 pandemic. The article further provides a comprehensive review of individuals who make use of technology in the COVID-19 era, as well as seeks to question the influencing factors responsible for technology dependency among individuals during the COVID-19 era. Consequently, the review seeks to establish the role of technology in supporting individuals during the COVID-19 pandemic. It also explored further how dependency on technology influences individuals in the long run, especially in the post-COVID-19 eras. Moreover, the possible social and technological challenges from technology dependency have been investigated as well and exploded further in a systematic mapping. Finally, the review answers the question as to how technology dependency changes the way an individual operates daily. More so, the investigation of technology dependency in this article provides recommendations alongside open challenges that can help stakeholders, the end-users, as well as technology developers in ensuring appropriate considerations are put in place when developing emerging technologies both for the current COVID-19 situation as well as to ensure a better life for the populace in future pandemics. There is minimal attention given to the investigation of a well-linked improvement tailored toward a comprehensive understanding of technology dependency and its impact on individuals, specifically regarding social and psychological aspects of the COVID-19 pandemic. Moreover, a systematic literature review that provides extant proof of the impact of COVID-19 via a comprehensive scope of technology covering multiple directions in extensive research is still lacking. This review thus is aimed at characterizing the dependency of technology as well as its impact on individuals during the COVID-19 pandemic, based on a specific field/sector, the technology used, and how this technology impacts the users, into a comprehensible taxonomy. Such kind of investigation is of much importance in analysing COVID-19 to determine the relevance of technology as well as its dependency value and impact on the current pandemic. Additionally, a systematic mapping is done on the impacts of technology usage. More so, the article can serve as a reference point for policymakers as well as stakeholders of diverse kinds of technologies. The contributions of this article are summarised thus:

1. State-of-the-art technology dependency, impact, and COVID-19 classification taxonomy are provided. Here, scholarly works in various fields are reviewed against such classification.
2. Motivation, open challenges, and top-notch recommendations of the integrated study fields are identified.
3. Comprehensive discussion and analysis on the identified sets in point 2, are conducted based on the following facets: (i) how individuals use technology in the COVID-19 era, and (ii) What influenced the

dependency on technology among individuals during the COVID-19 era? (iii) How does technology support individuals during the COVID-19 era? (iv) How does the dependency influence individuals in the long run? v) What are the possible social and technological challenges from this dependency? and (vi) How does the dependency change how an individual operates daily?

## II. SYSTEMATIC LITERATURE REVIEW

This study was conducted based on the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA). Understanding a research interest via a comprehensive means for specific topics is achievable, alongside the presentation of additional information for future studies by utilizing the PRISMA protocol [12], [13]. Moreover, systematic reviews are an outstanding technique due to their enormous impact on diverse scientific research areas and fields of study. Thus, principally, a systematic review includes a variety of processes, alongside search techniques, data sources, eligibility criteria, study selection, and data extraction respectively [14].

### A. INFORMATION SOURCE

Article search was conducted from relevant online databases, namely: (1) ScienceDirect, a popular database containing a large corpus of papers from the sciences and technology field, published in high-impact journals; (2) IEEE Xplore, this database provides abstracts as well as some full-text papers with a major focus on computer science, electrical engineering, and electronics. It is very normal to have more technically based papers in this database, such as how the technologies are developed; (3) Scopus, which houses a massive database of abstracts and citations, of scientific journals, alongside conference proceedings and books; (4) Web of Science, comprises research from multidiscipline, focused more on the fields of social science, humanities and arts, technologies. All these databases contains both technical as well as scientific studies from a wide range of relevant disciplines.

### B. SEARCH STRATEGY

A comprehensive literature search was conducted in the aforementioned databases. The search process was conducted over 2 months starting from February 1, 2022. This was achieved following the initial drafting of the manuscript major highlights. After the first search was conducted, another search was conducted on March 1, 2022, to confirm the inclusion of updated and recent articles. Selected databases advanced search features were utilised. Regarding the keyword search, two groups of keywords, alongside respective Boolean operators (such as AND, and OR) were employed accordingly, depending on the database strategy. For search and filtration of articles, diverse types of publications (original research articles, review articles, as well as conference papers), all covering updated, recent, and relevant articles, tailored to the review topic in lieu were put into consideration. Furthermore, the generation of the search strategy was achieved based on the following keywords by

TABLE 1. Search strategy.

Strategy	Explanation
Literature search	The first search started on 1 <sup>st</sup> February 2022 while the second was conducted from 1 <sup>st</sup> March 2022
Keyword search	Two groups with Boolean operators
Search and filter	Recent and relevant original

the search strategy of specific databases: ('Technology' OR 'Technology Usage' OR 'Technology Use' OR 'Technology Dependency' OR 'IoT' OR 'health care') AND (COVID-19 OR COVID-19 OR Pandemic OR COVID-19 Pandemic). Table 1 summarises the search strategy:

### C. ELIGIBILITY CRITERIA

In this review, the following criteria were applied in selecting the related and relevant studies from the respective databases:

1. The article is written in the English language and published in an English journal, original research paper, review, or conference paper.
2. The article is not older than 5 years from the date of writing. Most of the articles are from the era of COVID-19, from the year 2019 to date, precisely. However, some articles which focused on technology use in general even before the era of COVID-19, and were deemed of relevance to the current study were selected.
3. The article focuses on the use and dependency of technology, alongside technology impacts during the COVID-19 pandemic.

### D. STUDY SELECTION

This review employed a three-phase search process. The process comprised: article collection; title and abstract scanning; and full-text reading. Further, each article was subjected to a process of scrutiny by at least two reviewers to ensure all criteria for inclusion were adhered to and that the extracted data was accurate. Thus, in scenarios where there was a divergence between the two reviewers, a senior reviewer was invited to resolve the issues. Consequently, the quality of the included articles was evaluated to establish their significance to the review. In total, about 5,031 articles were retrieved from the selected databases in the first sub-phase. However, there were 150 duplicate articles detected across the total databases scanned. In the second phase process, titles and abstracts were scanned to identify all the associated articles. Thus, all the articles were examined via analysing and carefully reading the title and abstract in a comprehensive manner to ascertain that all criteria for eligibility were met amicably. Afterward, a total of 4,805 articles were excluded from the review. Consequently, all articles deemed eligible were subjected to the third phase, wherein full text was read, and all relevant details were obtained leading to a collection of the final reviewed articles ( $n = 76$ ), which fully met the inclusion criteria. It is important to state that in the course

**TABLE 2. Data extraction and classification of contents.**

Strategy	Description
Title	Title of article
Year	Year of article publication
Theme/Sector	Classify articles into taxonomies
Type of Technology	Classify into specific technology used
Aims/Objectives	Establish motivation of previous studies
Method/Approach	Understand techniques used in past works
Findings/Results	Gather the main achievements of past authors
Limitations/Future work	Outline gaps in previous works & gather recommendations for future
Conclusion	Summarize previous work/additional recommendations

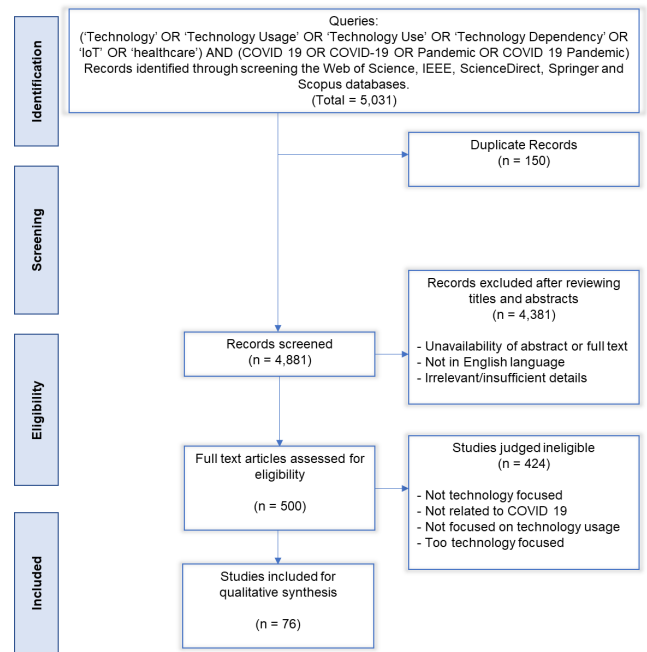
of this process, notes and comments (extraction of data) of the various articles were gathered, thus providing insights as well as helping in determining the final review format. Fig. 1 presents the taxonomy of related studies.

**E. DATA EXTRACTION AND CLASSIFICATION**

Extraction of required data was obtained from each article and subjected to further analysis. Several attributes were classified and itemised via an Excel spreadsheet to ensure consistency and avoid repetitions. Table 2 presents the attributes. As presented in Table 2, all illustrated attributes were deemed the most relevant for achieving the crucial points of this systematic review. Thus, each element was selected purposefully. For example, the title of the article was obtained as a reference for future work. The keywords were used in establishing the relevance of the article to the subject of review. The theme/sector was used in classifying the articles into different taxonomies, such as health, and education, among others. The type of technology was used to classify the articles into specific technology types used to achieve particular purposes during the COVID-19 era. The research problems were obtained to understand the background of the studies, as well as keep for future reference. The aims/objectives were obtained to establish the motivation for the previous studies. The method/approach was used in understanding the techniques used in achieving the postulated goals of the researchers. The findings/results were used in gathering the main achievements of the various previous papers in review. The limitations/future work outlined the gaps in the previous works as well as future recommendations which provided the perspectives of the previous authors that can be projected in this review to upcoming researchers in this field. Finally, the conclusion presents more summary details of the work as well as provided additional recommendations for future work from the past authors. Figure 1 illustrates the PRISMA diagram for the systematic literature review.

**III. TAXONOMY**

All articles included in this systematic literature review have been shown in Fig. 1 above. In total, about 5,031 records were



**FIGURE 1. PRISMA diagram.**

retrieved via searching the aforementioned databases. After removing duplicates (n = 150), about 4881 records were reserved. After reviewing the titles and abstracts, a total of 500 articles met the initial criteria for selection. Furthermore, about 76 articles met the requirement for inclusion and were part of the final review, after proper examination of full texts. These articles have been split into three major categories leading to the formation of a taxonomy for the study. The first category comprised articles discussing the type of technology used during the COVID-19 pandemic, followed by the second category which focused on the Dependency on technology during the COVID-19 pandemic. Moreover, the third aspect discussed the Impact of Technology during the COVID-19 pandemic. The three patterns underwent critical observation, which was followed by a general categorical summary, resulting in a taxonomy of literature, as illustrated in Fig. 2. Although, the main phases were able to identify sub-categories, however, there was an emergence of overlaps. The following subsections discuss critically the observed categories, thus answering the research questions, which finally map our final recommendations and open challenges from the review.

**A. TECHNOLOGY TYPE**

In this section, a view on the type of technology used during the COVID-19 pandemic is discussed comprehensively. Also, the prevalence of technology type which eventually leads to dependency as presented in subsequent sections is established in this section. From the taxonomy of studies, there were about 6 prevalent categories of technology used in various forms and for diverse purposes during the COVID-19 pandemic as reported by literature. They comprise healthcare

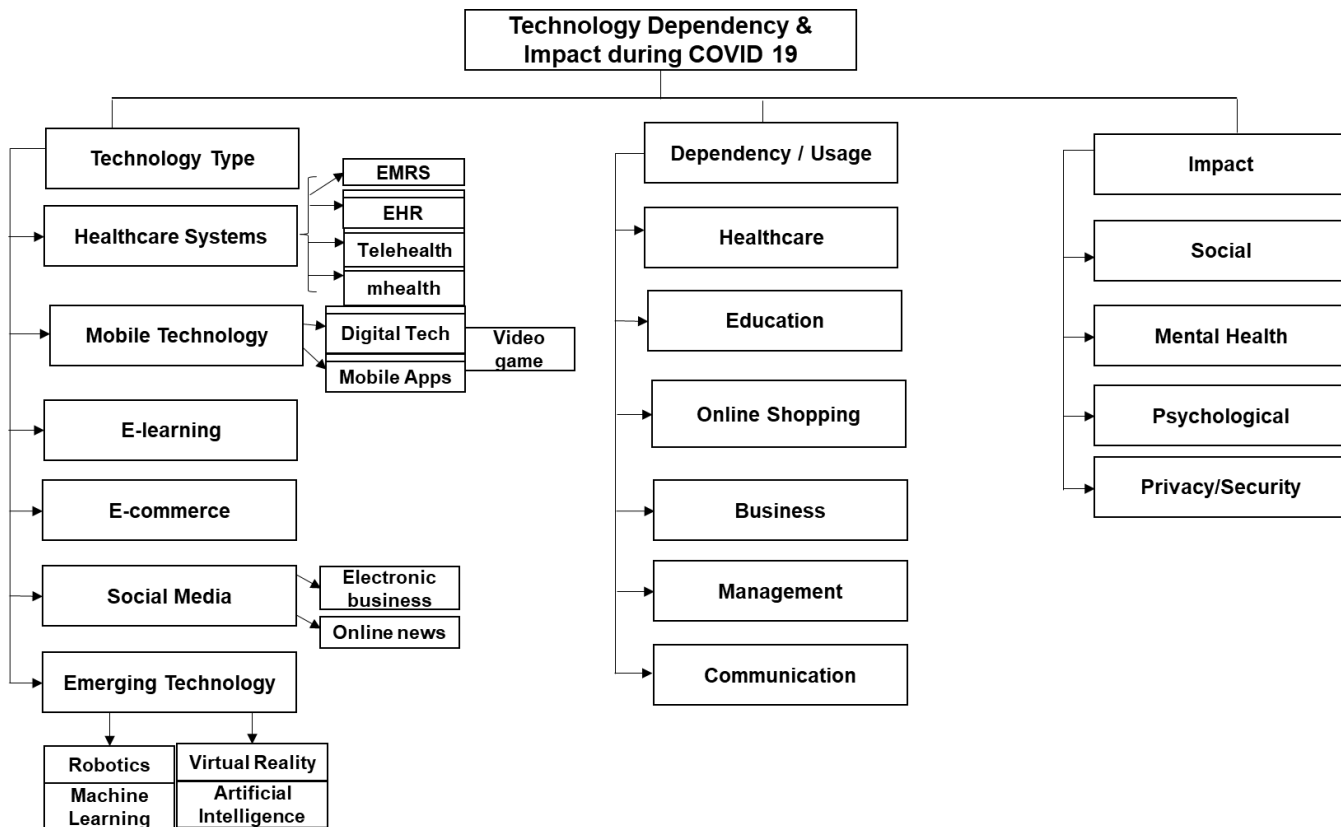


FIGURE 2. Taxonomy of related studies.

systems (EMRS: Electronic Medical Record System; EHR: Electronic Health Record); telehealth, and mhealth: mobile health), mobile technology (digital technology; mobile apps; video games), E-learning, E-commerce, social media, and emerging technology (robotics, virtual reality, machine learning, and artificial intelligence).

1) HEALTHCARE SYSTEMS

Far back in 2005, the potential of employing information communication technology (ICT) systems has been recognized by the World Health Organization (WHO), in helping to transform health delivery systems and services positively, thereby urging member states to set up long-lasting strategies for the use of ICT in the health sector [15]. Consequently, with the current pandemic in place, the role played by information technology in health systems has been accelerated. Such advance is prevalent in the field of telemedicine, information systems, as well as digital technologies. Corroborative, the lack of interoperability alongside additional crucial functionalities of electronic medical records (EMRs) has been exposed. This is also in line with issues related to end-users that are responsible for capacity hindrances in providing real-time access to patient information as well as ensuring referral systems that are well integrated [10]. Literature is extant with studies dwelling on the use of technology in the healthcare sector, especially during the era of the COVID-19 pandemic.

One such study examined the adoption as well as utilization of EMR technology in rural primary care settings. Their study revealed a non-parallel level of EMR utilization at primary care levels, thus instigating the need for a more granular approach to study adoption that can help in improving EMR usage quality, thereby contributing to the improvement of health service delivery and financing [15]. Similarly, in a qualitative descriptive study on the perception of nurses concerning the critical care work system during the COVID-19 pandemic [9], it was discovered that communication between patients and families was facilitated via iPad tablets supplied by respective organizations. Nevertheless, in most instances, there was the unavailability of such communicative technology supplied by the organizations, thus insinuating the nurses to make use of their mobile phones. Consequently, it has been revealed that at different phases of the pandemic, there were inconsistencies in the standard of documentation at health facilities [17], [18]. Thus, it is imperative to state that the presence of electronic health records might have helped in facilitating adequate documentation.

2) MOBILE TECHNOLOGY

The contemporary mobile phone is capable of going beyond the core role of just an ordinary device to communicate voice. Considering the technology of mobile applications alongside the smart concept, the mobile phone in this current

dispensation eases the life of individuals more than it has ever done [19]. Across the globe, the COVID-19 pandemic has affected people both directly and indirectly. Nevertheless, literature has revealed that advanced mobile phone technology is capable of providing sophisticated solutions that can help in coping with the pandemic [20], [21], [22].

Furthermore, there is an indistinct limit through digitization cutting across technology and management, leading to the facilitation of new business models being integrated into methods [23], [24], concepts as well as tools of the digital environment, all tailored towards an emerging digital transformation. A corroborative recent study conducted an investigation aimed at finding evidence of how important technological innovations were with regard to practicing strategies for international business before and during the course of the COVID-19 pandemic [23]. This business model transformation as supported by digital technology depicts its core strategy that is used as a responsive measure to ensure disruptive changes in the environment. Results from this study reveal a consistent variation of focus, occurring in certain sectors of activity in utilizing technology for association sustainability. The emphasis in literature with regards to digital technology is on its link with business, specifically in carrying out business operations via mobile apps during the COVID-19 pandemic era where face-to-face meetings were reduced drastically.

Moreover, as steady improvements emerge, there are several research challenges erupting, coupled with technological advancements which have increased variation in the market from traditional brick and mortar companies transforming into more digital options, mostly via mobile technology. However, there is a concern as to the user experiences both online and offline. In a recent study, the authors evaluated digital features responsible for the altering of customer behaviours to reveal underlying demands that analyses change in need and desires concerning furniture purchasing [24]. Their results revealed that when consumers engage online, they get motivated, thus resulting in a change in their attitudes and behaviours respectfully. More so, it was established that there is a need for an exciting offline experience that could help provide for consumer needs as well as improve buying behaviours of consumers. Realistically, there has been an acceleration of digitalization trends in the present era of the COVID-19 pandemic as well as the possibility of rapid development of digital technologies [25]; thence, it is necessary for firms to constantly update their digital transformative processes.

### 3) E-LEARNING

E-learning, the incorporation of technology and education, is described as an essential learning medium, that offers incredible advantages that help in redeeming the interactivity between instructors and learners from the limitation of space and time [26], [27]. Apart from teaching and conducting classroom activities, other e-learning tools have been used in

conducting examinations, as well as evaluating student performances during and after the COVID-19 pandemic. A study was conducted to evaluate the efficacy as well as the utility of an electronic Objective Structured Clinical Examination (e-OSCE) during the COVID-19 pandemic era [28]. The authors asserted that the e-OSCE tool was valid both in its usage and efficacy while ensuring safety precautions for users during the COVID-19 pandemic. Thus, it seems that students, examiners, and organizers were satisfied with the use of an electronic tool in conducting exams, however, challenges still exist.

Many conferences were held virtually during the COVID-19 pandemic era and most of these technological measures would be sustained as an alternative option after the pandemic is gone. It is therefore essential for stakeholders as well as developers to consider major factors that can help make these educational tools interactive enough by integrating emerging technology such as IoT, virtual reality, and artificial intelligence among others. Flipped classrooms have also been established in literature to help in overcoming some negative aspects of the transition to remote learning [29]. In recent research, it was discovered that students' learning attention, as well as course evaluation, was enhanced as a result of employing a combination of Flipped Classroom and online teaching. Moreover, the flipped classroom has been known to create a form of connectedness among learners and teachers, thus initiating a social presence. E-learning technology is an essential tool used by both learners and instructors to achieve continuous running of the academic journey as the COVID-19 pandemic is still in sight.

### 4) E-COMMERCE

Recently, there has been a substantial increase in the global consumer adoption of online shopping. Consequently, with the presence of a pandemic such as COVID-19, there seems to be a trigger in the migration of consumers from conventional shopping at malls and grocery stores to online shopping for literally all daily needs. A Finland-based study explored household and demographic characteristics as the underlying factors responsible for adopting online grocery shopping during the COVID-19 pandemic [11]. Their results indicated that demographic alongside household characteristics and health-related worries, significantly identified the adoption of online grocery shopping in the COVID-19 era. It is however feasible to predict a higher rate of e-commerce adoption even after the COVID-19 pandemic as many would have gotten familiarised with the trend and ease of shopping without having to leave their comfort zones.

The COVID-19 pandemic has shifted buying behaviours of buyers toward electronic trading platforms. Due to this, e-commerce is flourishing in this era more than other kinds of online businesses. Nevertheless, some changes are not easily captured by sellers as there is the non-existence of an e-commerce history of such magnitude. As witnessed and argued in literature, there is a reduction of tradition

in economic activity on a global scale as a result of the COVID-19 pandemic [11], [30]. Despite this, e-commerce activities have been enhanced. Thus, a challenge is being posed for retailers to join the train of e-commerce if they are determined to succeed in business at this critical period.

## 5) SOCIAL MEDIA

Via the use of social media and the Internet, most contemporary collective actions in society have now shifted online (such as petition signing) or perhaps maybe coordinated virtually (such as political violence, demonstrations, and product boycotting). Social media can trigger interactions, where collective actions could include supporting or indicating an interest (liking) on diverse social media platforms (Facebook, Twitter, YouTube, amongst others). A recent study revealed the manner of response to be adopted by public relations and communication fields to issues as delicate as racial injustice, which could cause threat as well as lead to compromise of societal well-being [31]. Similarly, another research examined the use of the Social Virtual World (SVW) as a potential coping technique to mitigate stress and anxiety linked to the COVID-19 pandemic [32]. It is paramount to state that the current pandemic poses a threat to the populace, not just as a risk of ensuing distress economically and to human life, but also has some psychological impact. Unfortunately, this sporadic pandemic could be specifically challenging for persons with underlying mental health conditions such as obsessive-compulsive disorders or anxiety [33], [34].

## 6) EMERGING TECHNOLOGIES

The importance of emerging technologies to serve as strategic levels in enhancing societal development alongside city management has been investigated in literature from the context of smart cities [35]. Before the COVID-19 pandemic, the contribution by smart technologies had led to the redesigning of urban area configuration. However, due to the impact of the technological revolution in smart cities, it is imperative to state that intelligent tools do not barely precede innovation and well-being achievement [36], [37]. Thus, it is essential to adopt technology, however, it may not be sufficient enough for the redefinition and readaptation of an effective organizational model postulated to overcome health emergencies. A study examined how COVID-19 perceived impacts results in diverse usage of virtual reality (VR) as well as investigated the importance of social interactivity within virtual reality in enhancing intention to adopt [38]. From the results, it was noted that the impact perceived by the pandemic influenced the possibility of acquiring VR for purposes of work, education, and tourism respectively. Also, while validating the importance of diverse applications used during the pandemic, it was discovered that the need for social interactivity serves as a mediation between COVID-19 impact on adopting future intentions.

Some scholars informed from their study that the technological field of artificial intelligence (AI) and robotics has

achieved a lot of accolades in settling the crucial needs of the health sector in the era of the COVID-19 pandemic [12]. Thus, novel solutions are being provided by innovators alongside researchers to solve the emerging challenges in the healthcare sector as a result of the COVID-19 outbreak. It has been deduced that emerging technologies such as robotics and AI place significant massive roles in solving issues such as diagnosis, assessment of risks, surveillance, tele-healthcare, supply chain and delivery, disinfection, service automation, and the acceleration of drug and research development [17], [22], [39]. The COVID-19 pandemic is still in a continuous state, thus, innovative as well as efficient contributions of emerging technologies in solving pandemic issues are still being researched. It is therefore imperative to state that digital technologies may not necessarily proffer final solutions but could serve as facilitating tools for an effective rapid response to the pandemic. Literature is extant with discussions on how COVID-19 can be tackled with the deployment of mobile applications, robots and drones, television, and social media platforms (e.g., Twitter, search engines, and Facebook), amongst other relatively novel technologies [35], [40], [41]. In healthcare, diverse countries seek emerging technologies that can help support their public health initiatives to balance a strike between the pandemic and normal life. Thus, emerging technologies such as mobile applications, Artificial Intelligence (AI), robots, drones, machine learning, and IoT are found to be of much relevance in healthcare.

Table 3 summarises the discussion on the first item in the taxonomy, technology type as previously discussed:

## B. TECHNOLOGY DEPENDENCY

Technology dependency refers to a short- or long-term reliance on technological appliances and tools, such as machines as well as techniques that could be used for evaluation, satisfaction, or to resolve a particular problem, ranging from health challenges, ease of academic presentation, business transactions, transportation, amongst others [4]. Consequently, some studies have discussed reasons for dependency on technology by users in various sectors, especially regarding the COVID-19 pandemic. As deduced from the systematic review, the major reasons why people depend on technology in this era of COVID-19 include healthcare, education, online shopping, business, management, and communication. The sub-sections shall discuss findings from past studies corroboratively.

### 1) HEALTHCARE

Healthcare is one of the major triggers of technology dependency among individuals in the era of COVID-19. Technology innovations in the field of healthcare have witnessed diverse advancements to ensure public health is assured despite the restrictions that come with the pandemic. In a recent qualitative study that tried to describe the impact of the COVID-19 pandemic on nursing care delivery, the authors

**TABLE 3. Technology type summary.**

Technology Type	Explanation	Literature
Healthcare Systems	The onslaught of the pandemic has exposed the gaps in technology adoption in healthcare. The lack of utilization of EMRs has become apparent which may lead to data inconsistencies, providing the organizations with unreliable information in a critical setting.	[9], [15], [16], [17], [18]
Mobile Technology	Mobile technologies have become increasingly prevalent and of cardinal importance in the COVID-19 pandemic. With restrictions in place on a global level, mobile technologies have served as an alternative method for completing daily tasks. Thus, due to the major shift from offline to online activities, organizations should accommodate this via digitalization.	[19], [20], [21], [22], [23], [24], [25]
E-learning	Various online learning tools have been developed to aid in providing students with an education during the pandemic. Despite the provided alternatives to physical classes, educators should assess the best method to conduct classes, either adopting a fully digital method or incorporating both digital and physical solutions.	[26], [27], [28], [29]
E-commerce	E-commerce has become integral to people's lives as well as businesses. The enhancement of e-commerce from preferability to necessity has forced businesses to explore and adopt digital solutions to maintain and expand their customer base.	[11], [30]
Social Media	Social media is a hub for activity, both good and bad. This includes the masses coming together for a common belief, which may bring about overzealous behaviour. This uptake of activity may be challenging to cope with.	[31], [32], [33], [34]
Emerging Technologies	The COVID-19 pandemic has forced wider adoption of technologies, not only with the vision to enhance people's lives but to adapt to times of crisis.	[12], [17], [22], [35], [36], [37], [38], [39], [40], [41]

informed that nurses used several novel technologies in overcoming barriers to patient care [9]. They further described that they had to depend on technological devices such as social media, and podcasts, to learn from their colleagues across the globe on how to care for COVID-19 patients. More so, novel technologies such as mechanical chest compression devices were said to have been employed to provide safe

and effective cardiopulmonary resuscitation while mitigating the harm that can be caused to staff. The dependence on technology to perform healthcare procedures was on a rise during the pandemic and may even be in higher demand after the COVID-19 era.

Since the pandemic erupted, telehealth has surfaced from diverse perspectives. Nevertheless, there is still a need for advanced investigations. Notwithstanding the category, literature has emphasized the hindering challenges towards maximizing telehealth in the current dispensation as well as seeking ways on the manner of addressing them [14]. In a recent study, authors revealed the need for systematic protocols in serving as guidelines on how to utilize interventions of telehealth in a way of responding to COVID-19 outbreaks [42]. Thus, health care practitioners need to be aware of the necessity to employ strategies tailored towards telehealth in improving facility outcomes in the course of the pandemic. A recent study was conducted to examine affective factors of the intention and actual user behaviour on the adoption of mHealth in the COVID-19 pandemic era [43]. From the findings, it was discovered that factors such as performance expectancy, effort expectancy, social influence, facilitating condition, hedonic motivation, and health consciousness, significantly determined the behavioural intentions towards mHealth service adoption. Thence, the confidence of users is perhaps lifted via the use of mHealth services which invariably enriches their mental well-being [12]. It is therefore paramount that technologies that can help improve healthcare services are on the rise, however, there is still a lack of studies with regards to how these healthcare technologies can balance privacy and mental wellbeing while serving the primary purpose of providing healthcare services.

## 2) EDUCATION

Since the COVID-19 pandemic started, most educational institutions at all levels stopped face-to-face learning to contain the pandemic, thus resorting to other measures via the use of technology to ensure education is not halted completely. Interestingly, the majority of institutions even at this time when the COVID-19 pandemic is in the process of being contained, still employ a hybrid style of learning – where students have the choice of either attending physical classes or joining their lectures virtually. Some of the e-learning tools employed during the COVID-19 pandemic that is paramount in literature comprise, blackboard collaborate, Zoom, Microsoft teams, and Moodle, amongst many others. It has also been noted that various tools are being developed by institutions to ensure the facilitation of work as well as maintain daily pedagogical continuity and enhancement of distance learning [44]. This is so because there is no suitable e-learning tool that can cover all kinds of teaching situations. A recent study tried exploring the existence of a digital outcome divide between rural and urban students under e-learning conditions in the course of the COVID-19 pandemic [26]. From their findings, it was discovered that there was an existence of a digital



outcome divide between urban and rural students, as those from rural areas had a low level of behavioural engagement in e-learning courses compared to their colleagues from urban settlements.

A study discussed the influence of the COVID-19 pandemic on mobile learning experience response [45]. The results indicated that perceptions of mobile learning's content quality, connectivity to the system, and user interface, were affective factors of easiness and perceived mobile usefulness, which also affects the experience response of learners. Thus, in the mobile learning environment, there is a need for students to have a clear well-structured interface that can enable them to easily search, find and digest knowledge. It has been postulated that the aforementioned will produce an enhanced perception level of the easiness and benefit of the system. Mobile learning helps students to achieve their learning needs without restrictions. Also, learners can engage in outside class formal learning activities as well as gain access to learning materials without being restricted on schedule. During the COVID-19 pandemic, the majority of institutions adopted different educational technologies to increase interactivity and engagement in virtual classes. Collaborative learning via facilitation of interactions in the learning community was also put into consideration in the choice of educational technology during the pandemic. There are benefits attached to online learning as confirmed by literature, such as increasing creativity of learners [45], self-regulation enhancement [46], building collaborative capacities [29], and improving the academic result of students [47].

### 3) ONLINE SHOPPING

It is no longer news that smart mobile devices are now among the most frequently used gadgets which serve as assistants to consumers in their daily living. In a pilot study, the authors focused on Polish consumers' mobile phone usage behaviour towards their online shopping-buying behaviour before and during the COVID-19 pandemic [19]. From their findings, it was revealed that the current pandemic had an impact on the usage of mobile phone apps by respondents for purposes of shopping online. Invariably, users were trying to cope with the pandemic challenges as well as avoid the corresponding negative consequences of the COVID-19 pandemic, thus resulting in users carrying out online shopping transactions more often during the pandemic as compared to before the COVID-19 pandemic era. E-commerce has witnessed a predominance in this era of the pandemic, where retailers have put in efforts that build, enhance, and promote their online stores. According to a recent study, online stores that were not managed by some small retailers before the pandemic erupted, have devised means of selling their products virtually (such as using social media as a means to advertise their products, or by offering pick-up or delivery services) [19], [48].

There is a complementary link between online and offline shopping mediums as compared to competitiveness [48]. As retail seeks more novelty, most consumers have transited

from offline retail mediums to online channels that are safe and convenient. Most customers before the COVID-19 pandemic have made use of offline shopping mediums, however as the situation of the pandemic is still ongoing, many consumers actively make use of online shopping channels for specific needs. Although some of the rules imposed by many governments on social distancing are gradually being relaxed, the trend of online shopping in doing business is increasing.

### 4) BUSINESS MANAGEMENT

Businesses are being run via online measures during the pandemic, wherein companies invested in novel technical solutions that can help enhance platform performances as well as enable better management of businesses by partners on the respective platforms [49]. Moreover, some businesses have also offered discounts on their online channels as well as introduced social media promotion campaigns to make the business run smoothly and minimise losses even with the restrictions brought by the pandemic. Research has projected the importance of investigating the online purchasing motives of consumers during the pandemic. As indicated by findings from a study on online shopping motives during the COVID-19 pandemic, it was revealed that there is an influence of media reports alongside expert opinions on the intentions of consumers to purchase online [50]. Consequently, past studies have also underlined that younger consumers actively make use of social media [51]. Thus, it is possible to insinuate that media influence is stronger among the younger generation than those of the older generation, as this might affect buying behaviours of consumers. People are likely to be dependent on media-reported information as well as those generated from experts compared to the information obtained from friends and families, as it is believed that experts provide timely information related to the current economic situation.

Technological advancements have significantly impacted businesses, most especially small and medium scaled retail businesses, by introducing e-commerce. As informed by a recent study, the mobile device is now the most acceptable technology utilised by the public for the enhancement and advancement of personal life and work goals, and all these are now being incorporated into digital payment methods [23], [52]. A study investigated on the continuous intention of utilising digital payment solutions in online transactions during the COVID-19 pandemic era [53]. From the findings, it was revealed that factors such as satisfaction, perceived ease of use, social distancing, and attitude, were significant determinants of the intention to continuously used digital payments. It can be thus recommended that institutions and policymakers should put the aforementioned factors into consideration in the course of developing digital payment systems for businesses.

### 5) COMMUNICATION

With the unexpected changes to remote work which is posing various novel practices to organizations and firms, it is

essential to establish the consequences of communication technology utilization alongside remote work on relational communication and its link with working culture. Thus, with the COVID-19 pandemic in question, relational communication is somewhat halted from regular face-to-face meetings and swiftly transitioned into remote work, especially in public sectors [5]. Most of the related works in literature have focused on public sector workers due to their well-known formality as well as bureaucratic working systems, which has further mitigated the essence of informal communication [22].

Among such studies on communication is one which investigated relational communication perception of employees in full-time remote work in the public sector [54]. Findings revealed that there is a diversity of relational communication among organizations, thus highlighting the significance of coping and well-being. Practically, the challenge between remote work and relational communication is linked to experiences of the manner as well as places for relational communication being lost as work is now drifting towards online measures and dependent on technology. Thence, a significant role is being played by communication technology for workers to enjoy support from their supervisors and work community remotely. Nevertheless, communication challenges seem to have increased as the majority of workers have no clue on how to use specified communication technology [55]. It was also revealed that virtual coffee breaks are not as interesting as physical office spaces present, yet communication partners have no choice but to depend on such available technologies to curb the spread of COVID-19.

Table 4 summarises the discussion on the second item in the taxonomy, technology dependency as previously discussed:

**IV. DISCUSSION**

This discussion section focuses on the third part of the taxonomy which covers the impact of technology as presented by scholars from the systematic review. The impact of technology on users during the COVID-19 pandemic era has been discussed comprehensively based on the review of the literature. Apart from just depending on technology for certain purposes, there are certain aspects revealed by literature on how this usage of technology influences or impacts user behaviours, especially in the era of the COVID-19 pandemic. Prevalent in literature, the impact is categorised under four segments, namely: social interactions, mental health, psychological, and privacy and security.

**A. SOCIAL INTERACTIONS**

The restraints on face-to-face social interaction during the pandemic have affected how people think as well as their attitude towards social interaction, with the inclusion of online interaction. It is pertinent to state that physical interaction amongst individuals as restricted by most governments in the advent of the pandemic, may now influence the attitude of individuals to their overall social interaction, not mind-

**TABLE 4. Technology dependency summary.**

Technology Dependency	Explanation	Literature
Healthcare	Technology usage in healthcare includes knowledge sharing and health services. Telehealth is essential to ensure that the healthcare system does not collapse under the pressure of hospitalizations due to COVID-19. Thus, it is imperative that these technologies not only maintain and improve the healthcare system but do not act as a hindrance to those seeking help and knowledge.	[9], [12], [14], [42], [43]
Education	Educators and students alike have had to adopt technologies. However, the commencement of a fully online educational journey robs students of a sense of connection, despite the benefits of online learning. This has then led to the utilization of multiple technologies and tools to create a quality learning and teaching experience.	[26], [44], [45], [46], [47]
Online Shopping	The shift from traditional commerce to digital commerce is apparent. Consumers will opt for businesses that provide digital services instead of those which do not, thus forcing small, medium, and large enterprises (SMEs) to invest in the digitization and digitalization of their business processes, which may prevail in post-pandemic times.	[19], [48]
Business Management	The predominance of online shopping has compelled businesses to make an effective and immediate change to survive the pandemic. These changes not only include supply chain management and transactions, but customer service as well to improve retention and conversion rates and decrease attrition rates.	[23], [49], [50], [51], [52], [53]
Communication	Remote working has forced employees to become more task-oriented without the reprieve of social interaction. To gain a sense of connection and familiarity, communication technology is used, though less effective and challenging in and of itself.	[5], [22], [54], [55]

ing if it's a face-to-face interaction or otherwise. Studies have revealed that some persons might have been considered unthoughtful for trying to be social during the pandemic [23], [32], thus may pose an impact on their actions in carrying out their normal social life if the pandemic were not to be. It is therefore highly recommended that future research should investigate the affecting factors of physical interaction

amongst individuals towards their online interaction attitudes. A recent study explored the emotional change of Twitch users during the COVID-19 pandemic [33]. From the results, it was discovered that the anxiety and anger of users significantly increased in the era of the pandemic, whereas sadness and positive emotion did not tally. With regards to social interaction, individuals uttered significantly fewer social words in the era of the pandemic as compared to before.

Literature has indicated likely links between virtual reality and social interactivity. In a study where virtual reality was adopted during the COVID-19 pandemic, it was revealed that social interactivity is a crucial factor to be considered when examining the adoption of virtual reality during the pandemic [38]. A recent study indicated a significance in the predictability of behavioural intention by social influence concerning mHealth services [56]. Thus, individuals with non-sufficient technological experience may be more inclined to social influence [23]. Social virtual reality also provides psychological benefits linked to self-expansion, enjoyment, and relatedness, all associated with immersive technique features. Via the use of social VR platforms, individuals can perceive an entertainable leisure time and may feel socially connected or belonging, thus temporarily relieving them from daily life challenges [38].

Furthermore, a study discussed the application of the social identity approach to digital intervention with a focus on loneliness in older people during the COVID-19 pandemic [57]. From the findings, it was revealed that there is a need for technology-inclined social connections to serve as a strategy that can foster the management of loneliness by older persons in the era of COVID-19 and after. Contemporarily, people make use of the Internet and video technology in bridging social distances during the pandemic [58]. However, it is being argued that these measures might not help in vehemently solving issues of social interactions, as a digital divide may be in place, especially for elderly persons due to a lack of digital communication skills and weak internet access [6], [59]. Other studies have affirmed that older people's technology dependency experience for social interactions is tailored towards technology usage in maintaining in-person relationships, such as having meetings via text messaging, or video calls to check on family and friends [60]. Therefore, it is important to state that more advanced technological innovations can help enhance social interactions both during the era of COVID-19 and after the pandemic has been contained.

## B. MENTAL HEALTH

There is a scarcity of studies on how technology dependency impacts mental health, especially during the COVID-19 pandemic, however, there are some records from literature. From a study which focused on how the digital divide amplifies the gender divide as linked with online learning, it was discovered that female students experience higher stress as online learning results in extra responsibilities at home dur-

ing the pandemic [61]. Another study examined the mental impacts of technology with a focus on online learning among Bangladesh students [62]. In their study, it was discovered that a huge amount of the students suffered from mental health issues during the pandemic. Literature has also revealed that major groups suffering from mental health issues based on the impact of technology are the elderly females in developing countries, alongside economically underprivileged children. This could be a direction for future work in this area. Mental health impacts of technology happen mainly due to a lack of awareness of stress, distress, and anxiety, alongside social isolation. It is extant in the literature that children are among the most vulnerable to experiencing trauma and a high rate of anxiety [6], [7], [8]. Thence, access to mental health services by such vulnerable groups can be increased.

Furthermore, research shows that the pandemic is responsible for many mental health issues brought via diverse psychological responses, such as depression, anxiety, negative feelings, and even as far as suicidal behaviours. In a study conducted in the UK during the pandemic, it was revealed that about 37% of participants make use of digital technologies in frequently addressing their mental health concerns and associated challenges [10]. Such mixed insights propose that though digital technologies are very beneficial and capable, they come with their challenges that can cause mental health issues in both tangible and intangible ways. Under the COVID-19 pandemic impact, it has also been revealed that social exclusion alongside digital exclusion has worsened the state of people's mental health. Narratively, several factors are responsible for the mental impacts of technology dependence during the COVID-19 pandemic on children and adolescents, this includes age, economic status, educational level, quarantined as a result of being infected, the fear of being infected, and underlying health challenges [63]. Additionally, it has been argued by some scholars that person with a psychiatric disability persons are even more prone to loneliness in this era of the pandemic, alongside worsening health inequalities [62]. The COVID-19 pandemic has brought debilitating barriers, which affect the vulnerable groups more, due to limited health and social care services.

## C. PSYCHOLOGICAL

At the time when the COVID-19 pandemic erupted, social networks took over the place of interpersonal interactions. Many persons were isolated at home. It has been established in the literature that psychological distress has a close relationship with loneliness. For example, people experienced more psychological distress due to their fear of contracting the disease. Thus, at this critical time, psychological distress was a norm for many across the globe. With regards to technology dependence and its link with psychology, studies revealed that students still experience psychological problems despite communicating via social networking sites (SNS) among other applications [5], [64].

The feelings of loneliness among individuals might trigger symptoms of psychological distress such as depression, anxiety, and stress alongside other health challenges, such as eating disorders [65], [66], [67]. Literature has also discovered that undergraduate students displayed gender differences as regards symptoms of psychological distress, wherein females were known to have suffered higher psychological challenges as compared to males [64]. Also, it has been revealed that verbal social skills alongside social networking could help in reducing loneliness feelings, thereby enhancing overall mental health, especially among female youths [68], [69]. Novel technological advancements such as smartphone mobile applications have been found effective in mitigating issues of loneliness as well as mental health improvement [21], [22], however other studies also revealed that other forms of technology such as social networking, and dependence on websites are linked with sleep problems and psychological challenges [70]. Some studies went ahead to predict that technology dependence especially during the pandemic might affect the academic performance of students, which in the worst case could even lead to an escalation in the rate of attempts to commit suicide [71].

Therefore, an increase in psychological resilience could be a potential drawback in enabling negligence among the populace regarding adherence to safety measures during the pandemic such as practising social distancing and wearing of facemasks. Nevertheless, a couple of factors exist as concerns the determination of either adopting or disregarding such measures and how this affects the perception of risk among the society, namely: socio-political systems, trust in science and government, and most importantly individual characteristics. In a study that discussed need satisfaction, well-being impacts as well as the passion for playing videogames during the COVID-19 pandemic, the authors provided evidence of how important videogames could help in providing satisfaction for the basic psychological needs of individuals [58]. Results indicated that there is a link between video game play and psychological distress coping, however, this was a two-sided impact – positive and negative. The negative impacts occurred when individuals played games with bad or problematic behaviours perhaps due to stress acquired by the pandemic challenges. Another study examined the use of the social virtual world in increasing the resilience of psychology during the COVID-19 pandemic [32]. From their research, it was discovered that SVW technology helped in reducing the fear of COVID-19 contraction as well as increased the psychological resilience towards the pandemic. There is no doubt that psychological distress has a very strong corroboration with technology dependency, especially with regards to the COVID-19 pandemic which may not be totally off the bridge for some years to come, thus, future research might want to ponder more on this aspect.

#### D. PRIVACY & SECURITY

Privacy and security while using technology is a continuing challenge even before the advent of the COVID-19

pandemic, however, it's more crucial in this period where data is obtained almost everywhere as the pandemic has made individuals and society rely more on technology. For example, it became a norm to scan at most public entrances before gaining access to facilities, such as malls, offices, churches, mosques, institutions, and hospitals, among others. Data is collected daily and little is known to the public as to how this data is being secured and the limitations to which such obtained data are being used. Though there is still a lack of studies on this subject matter, however, literature has some records. A recent study discussed the challenges of privacy and security in the course of technology used for tracking purposes during the COVID-19 pandemic [72]. Findings from the study revealed that despite the usage of technology in assisting governments as well as health agencies to mitigate COVID-19 spread, there is a spark of privacy concerns as to the motive of surveillance by the government. Protecting society against harm and threat to health includes gathering basic as well as health-linked data from the populace, especially in a contemporary society that depends much on mobile phone technology [17], [73]. Health authorities alongside governments can identify further steps in planning and implementation to ensure society is protected, thus positioning each individual as a key player [74]. Due to the pandemic, it was revealed that in many countries, mobile location data with advanced tracking capabilities were used to enforce quarantines [18], [72], whereas individuals' identities could be captured via facial recognition technology that is linked with biometric databases. Furthermore, a study argued that data mining via several sources of big data could help in the discovery of important information as well as knowledge, which could be transformed into proposing appropriate actions that can serve as a benefit to health agencies in the prevention and control of the disease [75], [76]. Thus, the protection of data obtained by technological devices should be of paramount concern as the monitoring of health and location data of a society populace is crucial in ensuring an effective strategy of containment, wherein personal data is currently being collected, used and dispersed in various ways.

Table 5 summarises the discussion on the third item in the taxonomy, impact, as previously discussed:

## V. SYSTEMATIC MAPPING

The systematic mapping process by Peterson et al. [77] was implemented to further investigate the research area of the impacts of technology usage during COVID-19. As shown in the taxonomy from the systematic review, there are four major impacts of technology usage. The systematic map will define the breadth of the literature in further detail. The details of the process are displayed in the figure below:

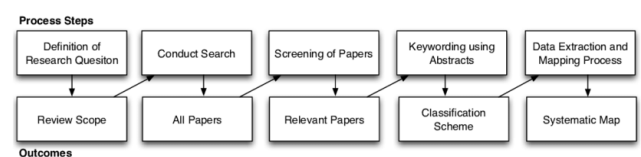
### A. DEFINITION OF RESEARCH QUESTIONS

### B. CONDUCT SEARCH

The studies are identified by searching scientific databases with specific keywords. The scientific database used is

**TABLE 5. Technology impacts summary.**

Impact	Explanation	Literature
Social Interactions	During the pandemic, physical social interactions have declined whereas online social interactions have increased. This change in social interactivity has affected users psychologically, forcing users to adopt other means to mitigate its negative effects.	[6], [23], [32], [33], [38], [56], [57], [58], [59], [60]
Mental Health	Despite mitigation efforts to continue daily life whilst adopting digital solutions in the pandemic, technostress is a common event. Additionally, inequality in technology access is a factor linked to the worsening of mental health.	[6], [7], [8], [10], [61], [62], [63]
Psychological	A large mass of people has difficulty coping with daily life due to the sudden changes and distress brought on by the pandemic, compelling people to adapt to the new normal. However, this induces strong feelings of loneliness and fear, exacerbated by the need to depend on technology primarily due to the loss of freedom.	[5], [21], [22], [32], [58], [64], [65], [66], [67], [68], [69], [70], [71]
Privacy and Security	Widespread technological usage in varying sectors has led to a substantial collection of personal data. Notwithstanding the potential benefits that can be reaped from the data, ethical concerns are at the forefront, leading to the question of where the line is drawn to ensure data protection, and fears, whilst putting the data to good use to be of service to society.	[17], [18], [72], [73], [74], [75], [76]



**FIGURE 3. Systematic mapping process.**

ScienceDirect. The following search string is used: (‘Technology’ OR ‘Technology Usage’ OR ‘Technology Use’ OR ‘Technology Dependency’) AND (COVID-19 OR COVID-19 OR Pandemic OR COVID-19 Pandemic) AND (IMPACT). The total number of articles retrieved from the database was 779, with the search string applied as above and filtered from the years 2019 to 2022 to ensure relevance to the pandemic era.

**C. SCREENING OF PAPERS FOR INCLUSION AND EXCLUSION**

The following inclusion and exclusion criteria were applied in the selection of relevant articles from the database as presented in Table 7:

**TABLE 6. Research questions.**

ID	Research Question	Rationale
RQ1	What are the most investigated impacts of technology usage in the COVID-19 pandemic?	To determine the distribution of literature in relation to the impacts.
RQ2	What is the most frequent type of paper published and what were their contributions?	To identify the most constituted contributions and verify the recurrent type of research done in this area of research.
RQ3	Which subset of studies has the least comprehensive state of knowledge?	To determine the gaps in research.

**TABLE 7. Inclusion and exclusion criteria.**

Inclusion Criteria	Exclusion Criteria
The paper is published from 2019 to 2022, during the COVID-19 era.	Social interactions, mental health, psychological, privacy and security, or other areas as impacts are not part of the contributions of the paper.
The abstract explicitly mentions the impact of technology usage and it can be deduced that the paper contributes to the impacts of technology usage in COVID-19 research.	Non-digital technologies and their impacts are not explicitly mentioned in the abstract.

**D. KEYWORDING OF ABSTRACTS**

The abstracts of all 779 articles found in the scientific database were read to determine the relevant concepts (from the systematic review/new). This was determined alongside the research type and contribution facets. This process takes into account the inclusion and exclusion criteria as mentioned previously. The following list details the indicators used to determine the relevancy of the articles:

- The abstract contains keywords such as: (i) impact of technology usage/dependency/adoption (ii) education/health/e-commerce etc
- The overview of the paper in the introduction were read where necessary, in situations whereby: (i) the authors could not objectively conclude that the paper contributed to the context of impacts of technology usage from the abstract itself (ii) the authors needed to confirm the research type and contribution facets

**E. DATA EXTRACTION AND MAPPING OF STUDIES (SYSTEMATIC MAP)**

The systematic map was reported in a bubble plot as illustrated in Fig. 4 below.

The four prior high-level categories of impacts as found in the systematic review were maintained in the systematic map. In addition, three other categories were found: physical health, socioeconomic, and environmental health.

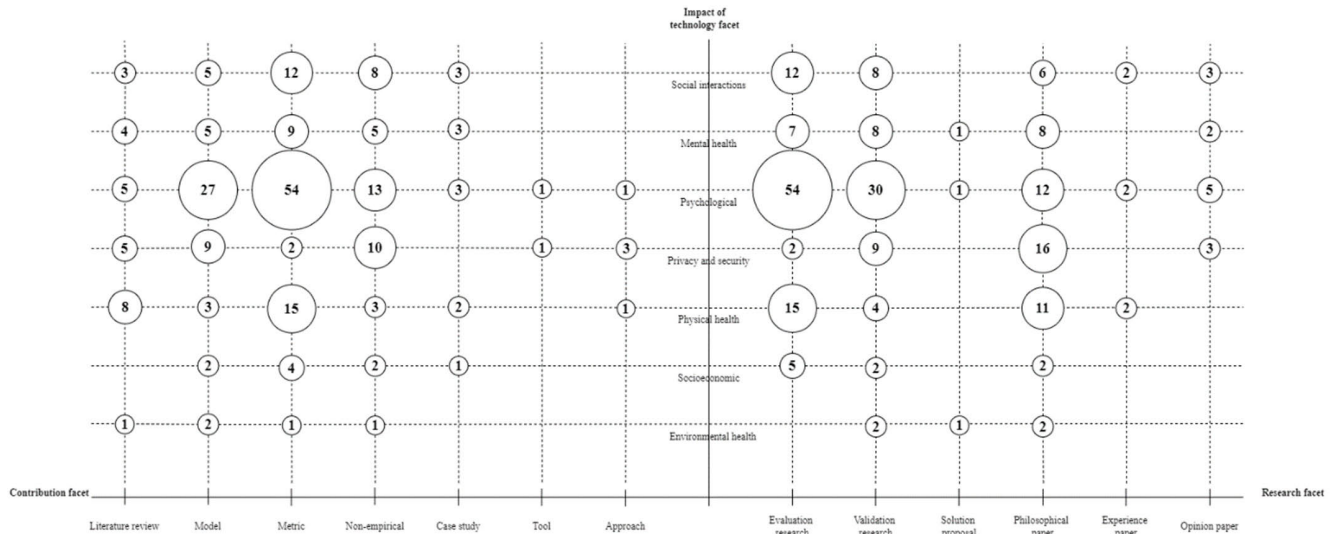


FIGURE 4. Bubble plot.

F. DISCUSSION

This section summarizes the principal findings of the systematic mapping study, a brief discussion on the three additional themes, alongside the limitations of the study.

1) PRINCIPAL FINDINGS

What are the most investigated impacts of technology usage in the COVID-19 pandemic?

From the systematic map, the most frequently published and studied impact of technology usage is the psychological impact. This is followed by social interactions, closely followed by physical health and privacy and security, and mental health. Consequently, there is a lack of research on socioeconomic and environmental health impacts. From the reviewed articles, it was observed that a number of them recorded multiple themes in the same study, for example, psychological and social interactions.

What is the most frequent type of paper published and what were their contributions?

All themes were found to have validation and philosophical research facets, and, except for environmental health, evaluation research facet. Major contributions of the studies were found to be models, metrics, and non-empirical studies. For psychological impacts, the highest studies are in the research facets of validation research and empirical research, and the highest number of contributions are metrics and models. In general, the highest contributions are metrics, followed by models and non-empirical studies, a close second to models.

Which impacts of technology usage has the least comprehensive state of knowledge?

Socioeconomic and environmental health impacts are the least explored impacts with 9 and 5 articles respectively. Hence, it can be deduced that this lack of research is indicative of a narrow knowledge pool. Further research could be

conducted for further exploration into this context with the following methodologies:

- Qualitative: Conduct interviews with experts and field observations
- Quantitative: Adopt experiment or survey methods and conduct the proper statistical analysis
- Mixed-method: Verify initial quantitative findings with the subsequent qualitative method

Findings in evaluation research are influential and can aid in the advancement of the creation of knowledge whereas validation research is the creation of new knowledge. Hence, these two research facets are empirical studies that directly contribute to the research area. Models, metrics, and non-empirical studies which constitute the bulk of the contributions still show the need for further empirical research, especially in areas other than psychology. Non-empirical studies could be used as a starting point for other points of research. Models and metrics as empirical evidence could be used to corroborate other qualitative or quantitative evidence or to provide a different conclusion.

2) PHYSICAL HEALTH

The adoption of digital technologies has its fair share of negative impacts alongside its positives. A study in India [78] found that, out of 122 participants, 95% (n=116), the excessive use of mobile technologies has led to an increase in health issues such as headaches and musculoskeletal problems. This is especially risky for those who develop an addiction to mobile technologies, especially in the advent where technology is on the rise. Technology usage has also caused implications for the healthcare system, especially where telehealth is concerned due to the rapid shift in the delivery of services. As further testimony to the previous elaboration on mobile technologies and their effects, a study [79] that discusses the use of telehealth in the diagnosis and treatment

of cancer, has found that constant technology use leads to technostress, which manifests itself into fatigue. The same study [79] discusses the physical limitations brought on by telehealth, such as physical inspections, examinations, and investigations. As per the policies implemented by countries worldwide, social distancing is a prominent policy instigated to curb the spread of the COVID-19 virus. Despite the restrictions, telehealth systems are implemented to support patients aside from the necessary clinical aspects such as diagnosis and consultation. A telehealth virtual reality (VR) system, XRHealth is used for supporting patients with various physical ailments, for example, by encouraging physical activity during quarantine [80]. These physical activities are valuable for maintaining physical health, especially for those with comorbidities.

A study in Japan [81] investigated the uptake and role of a contact tracing app to act as a commitment device in improving social distancing, which found that the app could assist with social distancing without the fear of mental health retribution. It has also been found that the need to avoid infections (Contamination Avoidance) is a major determinant in the adoption of teleconsultation [82]. This is especially true as the COVID-19 virus is highly infectious: spread may occur via airborne particles and droplets, or physical contact with surfaces. Another study focused on students in medical faculties and their physical tendencies during remote exams [83] discovered increased caffeine and junk food consumption, fewer sleeping hours and physical activity, and increased smoking habits. Stress induced by remote learning and exams causes physical health problems. The management in educational institutions should create a well-defined structure for e-learning to reduce the negative impacts. Therefore, studies on the benefits and drawbacks of telehealth and e-learning during the pandemic should give precedence to other factors such as readiness, socioeconomic status, and demographics, amongst others.

### 3) SOCIOECONOMIC

Socioeconomic impacts have been prevalent since the advent of technology adoption. This is because not everyone has the same stakes in this pandemic. This is further discussed regarding social standing. A study conducted in England that focused on target groups such as migrants, refugees, and homeless people discovered the digital exclusion faced by these groups of people [84]. As reported in the study [84], this was primarily due to limited access to the internet and technology. As the pandemic exacerbated the adoption of digital technologies for virtually all areas of service as well as information sharing, the lack of resources not only hindered their access to information regarding COVID-19 but also to online support groups and basic healthcare services. On the other hand, remote working has incurred costs for its workers which impacted their financial status. A study found that the costs incurred by remote working were primarily due to an increase in electricity use [85]. However, certain companies

did not provide workers with a personal computer (PC), forcing the worker to purchase their own, as well as bear the costs of internet connectivity and teleconferencing platforms [85]. This negatively impacts the economic-financial status of workers, especially those without the assets in the first place. However, it may be argued that remote working does reduce costs in the long run, as there is an omission of travel costs.

Students also faced a financial crisis due to the pandemic, as they were required to rapidly transition to an online environment. A Bangladeshi study in tertiary education [86] found that 79% of (n=380) respondents faced financial difficulties hampering all intentions to purchase electronic devices and internet connection. 21% of respondents (n=107) borrowed their friends, relatives, or family members' electronic devices to carry out online activities and complete assignments [86]. This income disparity is a testament to the effects of the digital divide, especially for those in developing countries. Automation and robotics have been implemented in mining industries, and although resulting in higher efficiency, the concern of jobs and inequality due to automation is at the forefront. Automation typically disrupts manual and menial jobs, taking over lower-skilled jobs, but also creating new jobs. High-skill workers, who typically manage the changes in technology and operations, will then gain an advantage as there is a higher chance of salary increase, placing the lower-skilled workers in an uncertain situation [87]. This will expand the digital divide, even between societies, widening the disparity in income levels, increasing dissatisfaction, and may cause other social problems.

### 4) ENVIRONMENTAL HEALTH

There is an ongoing debate on the effects of digital technologies on the environment, especially on whether digital technologies are worsening the environment, or if it helps improve environmental performance. A study on 25 European countries [88] reports that the short-term consequences of digitalization are adverse, whereas, in the long run, positive effects are apparent. The same study [88] states that the digitalization of businesses and digital public services directly impacts environmental health and ecosystem vitality, where environmental performance only improves in the long term. Digital technologies that have been adopted in the education sector have been shown to improve energy efficiency and lower-carbon alternatives to fossil fuels, and reduce pollution and waste, all whilst providing quality education in the United Nations [89]. Prevalent activities such as online shopping and remote working have been shown to reduce energy consumption and CO<sub>2</sub> emissions [90]. These sustainable technologies are in line to achieve sustainability, to achieve a better future.

The sharing economy is the facilitation of exchanging access to goods and/or services between parties which is enabled by the advent of technology. There is the opinion that the sharing economy promotes the emission of greenhouse

**TABLE 8.** Summary of technology impacts from the systematic map.

Impact	Explanation	Literature
Physical Health	Different viewpoints garner different effects on physical health, either positive or negative. The inevitable adoption of technologies may lead to fatigue, changes in dietary habits, etc., and, when used in excess, may lead to addiction. However, telehealth technologies have helped in curbing the spread of the virus, especially through social distancing, whilst providing options to promote physical activities.	[78], [79], [80], [81], [82], [83]
Socioeconomic	The sudden onslaught of the COVID-19 virus has pushed countries worldwide to adopt digital solutions to curb the spread of the virus whilst maintaining a semblance of normalcy. However, the adoption varies across countries, and within the country itself. This is due to multiple factors such as financial status, skill levels, readiness, as well as technological fluency.	[84], [85], [86], [87]
Environmental Health	There are varying opinions on the effects of technology usage on the environment. Efforts to develop sustainable technologies are ongoing and practices are enacted to encourage green practices to reduce the greenhouse effect and to work towards a sustainable future.	[88], [89], [90], [91]

gases, warming the planet's atmosphere and troposphere [91]. However, the sharing economy encourages the reuse and purchase of used items which avoids wastage of excessive resources and nurtures green practices [91]. This will help in sustainable development and maintaining environmental health. However, further research should be done to determine the short and long-term effects of such economies and the rapid transition to digital economies.

Table 8 summarizes the above discussion on the impacts.

##### 5) LIMITATIONS OF THE SYSTEMATIC MAPPING STUDY

The limitation of this study is related to the lack of scientific databases, misclassification, and inaccuracy in the data extraction process.

As this study uses only one scientific database, namely ScienceDirect, the articles explored are limited and may not encompass the whole scope of impacts of technology usage. Hence, the utilization of multiple scientific databases could potentially enhance the state of evidence through the provision of diverse levels of information. In addition, the broad scope and rapid timeline of the systematic mapping is prone to the exclusion of some articles. Misclassification and inaccuracy may occur due to the differing perceptions when extracting information regarding the study. Hence, some leeway was adopted by skimming through the content of certain

articles to further solidify the classifications and determinations of facets.

Although systematic mapping is a form of evidence synthesis and has thus reduced selection bias and publication bias, the limited usage of available databases may have impeded the reduction in bias.

## VI. RECOMMENDATIONS & CONCLUSION

From the review of literature, it can be asserted that technology might be an avenue for administering and ultimately enhancing health services (both physically and mentally), improving outreaches as well as helping in curbing the spread of diseases, such as is being portrayed by the current COVID-19 pandemic. However, the impact of technology dependence is not one-sided, as it has both positive and negative effects on the populace. It is also established that one of the crucial issues regarding the link between technology and health is its impact on the mental health of individuals. For example, video conferencing interventions, as well as smartphone interventions, have been found helpful in addressing issues related to mental health conditions, such as depression, stress disorder, and anxiety [92]. Thus, technology stakeholders might consider the mental health of users in the architectural design of advanced technologies. Lessons learned from the COVID-19 pandemic can serve as a trigger that can help in balancing the bridge between technology and how it directly impacts users, thus putting into consideration social interaction, mental health, psychological wellbeing, as well as privacy and security, to ensure individuals are satisfied with their dependency on technology.

Furthermore, the dependence of society on technology is on a rise during the COVID-19 pandemic, coupled with variances in socialisation and occupation, which might remain even after the pandemic is contained. Thence, society, stakeholders, governments, as well as the general populace must make and consider choices that are mindful and intentional concerning the manner of leveraging technology that can help enhance lives, mitigate stress as well as improve mental health. Imperatively, individuals should reduce the recurring exposure to what the media projects about the pandemic alongside accompanying social activities that trigger distress [31], be cautious about social media usage from a high-level perspective [33], [93], and avoid overload of work which may lead to psychological and mental health challenges [32]. With all the drawbacks being revealed from the literature, technology benefits are leveraged to enhance accessibility across a diversity of socioeconomic groups, thus ensuring the positive impact of technology is equally dispersed in society. Conclusively, the current COVID-19 pandemic provides open challenges and opportunities for researchers, stakeholders, healthcare personnel, employers, decision-makers, government, educational institutions, and individuals, to explore the best practices tailored toward pursuing an enhanced focused technology dependency that can mitigate the negative impacts of technology on mental, physical, and environmental health,



privacy and security, psychological distress, and socioeconomic, and thereby better the lives of the populace.

## VII. MAJOR CONTRIBUTIONS

This study attempts to address several research gaps and has hence made important contributions within the scope of this research. First, the study qualitatively synthesized available literature to develop a comprehensive taxonomy which exhibits various aspects of technology dependency and usage which were further explored in-depth. Secondly, through the extensive exploration and synthesis of literature, motivations, open challenges, and recommendations were put forth. Thirdly, to the best of the authors' knowledge, there is a lack of research that consolidated various scopes of technology usage and looked further into the impacts of technology. Hence, this is one of the earlier studies that focused on multiple areas of technology usage and its impacts.

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