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1	Postsecondary Mathematics during the Covid-19 Pandemic: A
2	Systematic Review
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7 Abstract

The Coronavirus 2019 pandemic has brought about the need for prompt and dynamic changes 8 in the educational system, including the use of e-Learning. Mathematics is a particularly 9 abstract field of study that may be difficult to teach through e-Learning. Psychosocial factors 10 pandemic may further challenge educators and students in mathematics e-Learning during the 11 pandemic. This systematic review aims to explore the transitional experiences of 12 postsecondary educators and students in mathematics e-Learning during the Coronavirus 2019 13 pandemic. Nine articles met the criteria and were included for synthesis. Findings revealed 14 that the most utilized and preferred technologies were Google Classroom, Moodle, and 15 WhatsApp. Changes in educators' practices included increased hours spent on teaching 16 preparation and tasks, reduced use of gestures, sending notes prior to lessons, and reduced 17 student interactions. Advantages of mathematics e-Learning perceived by educators included 18 improvements in student involvement, lesson planning, teaching style, and comfort in 19 technologies. Major challenges perceived by educators were reduced student interactions, lack 20 of special software for mathematics, difficulty monitoring student progress, and difficulty with 21 testing. 22

23

24 Index terms— covid-19, e-learning, higher education, mathematics, systematic review.

²⁵ 1 Introduction

he Coronavirus 2019 (Covid-19) pandemic, which began in December of 2019 in Wuhan, China, has had a 26 27 significant impact on various fields across the globe, including the field of higher education (Marinoni et al., 2020). Based on the United Nations Educational, Scientific and Cultural Organization (UNESCO) reports, 28 185 nations declared closure of their educational institutions beginning April of 2020, thereby impeding on the 29 education of around 1,542,412,000 learners (89.4% of overall enrolled learners) around the world (Marinoni et al., 30 2020). Such a large scale and dynamic change has never occurred before, and warranted extensive adjustments 31 to educational systems (Cassibba et al., 2021). Since then, several learners and educators have experienced 32 unforeseen radical reconstructions of education as they worked or studied from home (Neuwirth et al., 2020). 33 34 Both learners and educators have had to adjust to the new system of e-Learning.

35 E-Learning has been defined as the use of various types of information and communications technologies (ICT), 36 such as e-mail, software, and learning management systems (LMS), among others, for the purposes of education (Ayu, 2020). E-Learning is a part of the fourth industrial revolution (4IR), which involves the technological 37 integration of the physical, biological, and digital aspects of life (Sakhapov & Absalyamova, 2018). Although the 38 4IR began earlier than the Covid-19 pandemic, disparities in terms of readiness still exists between nations and 39 between individuals (Naidoo, 2020; Sakhapov & Absalyamova, 2018). Furthermore, although individuals may 40 be accustomed to using technologies for personal uses, e-Learning is substantially different (Nsengimana et al., 41 2021). The terms digital natives and digital immigrants illustrate the disparities in readiness (Naidoo, 2020). 42

43 Digital natives are individuals who are well-versed in the use of latest technologies, while digital immigrants 44 comprise those who are unfamiliar with technology and may tend to rely primarily on printed materials prior to 45 using digital technology (Naidoo, 2020). With the sudden adjustments made due to Covid-19, digital immigrants

46 may have difficulties transitioning to the digital lifestyle.

Other psychosocial factors may also be at play during the Covid-19 pandemic. Given the new virtual classroom 47 environment and possible distractions in the physical environment, the learners may have difficulties focusing 48 on their lessons or participating in discussions (Neuwirth et al., 2020). At the same time, educators may have 49 trouble adjusting to teaching on a screen with minimal visual feedback from and engagement from their students 50 (Neuwirth et al., 2020). In addition to these obstacles, Ludwig (2021) proposed the phenomenon of Covid despair, 51 which describes negative psychological state of individuals during the pandemic. During this difficult time, 52 individuals may struggle with financial stress, unemployment, cramped living spaces, lack of recreation, social 53 isolation, and immediate deportation of international students. Given these difficulties, the present generation of 54 young adults (Gen Z) were found generation in terms of mental health (Ludwig, 2021). Such psychosocial factors 55 may serve as additional burdens that can impact the transitional experiences of both learners and educators to 56 e-Learning during the Covid-19 pandemic. 57 58 Mathematics is a subject of particular interest for the topic of e-Learning. Cassibba et al. (2021) purported

that mathematics was a highly abstract field of study that involved a great deal of cognitive metaphors so that learners could objectify and understand mathematical topics with what they already know. As such, the use of gestures and body language was purported to be useful in helping learners to visualize the mathematical objects (Cassibba et al., 2021).

Mathematics is also known for its use of specific language and symbols, which should be supported in e-Learning platforms (Ahn & Edwin, 2018). Additionally, mathematics may best be taught synchronously to allow for practice (Nsengimana et al., 2021). Collaboration was also cited as a valuable factor for mathematics education to allow learners to work together on solutions for mathematical problems (Naidoo, 2020). The aspects of practice and collaboration, however, may be more restricted in e-Learning (Naidoo, 2020;Nsengimana et al., 2021).

Although various software have been developed specifically for mathematics e-Learning, use of such software in practice remains scarce because of the difficulties in setting them up and using them, in addition to the high costs associated with them (Ahn & Edwin, 2018). Mathematics education may thus need considerable adjustment from traditional face-to-face learning to e-Learning. A synthesis of the evidence on the current state of postsecondary mathematics e-Learning may be valuable to determine possible gaps and challenges that could be addressed or

74 improved upon for better transitional experiences of educators and students.

To address the issues presented regarding mathematics education in e-Learning during the Covid-19 pandemic, this systematic review involved the consolidation of the available data on educators' and learners' experiences.

77 The main research question for this review is: What are the transitional experiences of postsecondary educators

and students in mathematics e-Learning during the Covid-19 pandemic? This is divided further into four sub-

79 research questions:

$_{80}$ 2 Method

Systematic reviews are used to collate evidence regarding specific questions with a search strategy that is explicit, systematic, and replicable (Gough et al., 2017). The use of clearly defined inclusion and exclusion criteria is vital for the search strategy. The resulting studies from the search are coded and synthesized to arrive at findings that address the research questions, highlight gaps and inconsistencies on existing evidence, and serve as potential guides for practice (Gough et al., 2017). For this systematic review, nine articles regarding the topic of transitional experiences in postsecondary mathematics e-Learning were mapped.

⁸⁷ 3 a) Search Strategy

The inclusion criteria for this systematic review were peer-reviewed studies that were published in the English 88 language and involved postsecondary mathematics education during the Covid-19 pandemic, with the sample 89 of postsecondary educators, students, or both. As the Covid-19 pandemic began in December of 2019, the 90 search was limited to articles published in 2020 and 2021. Exclusion criteria were articles that had no full text 91 available, not relevant to the topic, and those in the forms of systematic reviews, meta-analyses, letters to the 92 Editor, commentaries, or theoretical articles. Following the Preferred Reporting Items for Systematic Reviews 93 and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021), a search was conducted on September 2021 94 using four databases: ERIC, Google Scholar, JSTOR, and MDPI, resulting in an initial number of 26,497 records 95 identified (see Figure 1). Search terms utilized are also presented in Table 1. 96

97 4 Year 2021

Postsecondary Mathematics during the Covid-19 Pandemic: A Systematic Review to be the loneliest and most
negatively affected Mathematics "mathematics" OR "math" Higher Education "higher education" OR "tertiary

education" OR "postsecondary education" OR "college" OR "university" Coronavirus "Coronavirus" OR "Covid"

OR "Covid-19" OR "SARS-CoV 2" e-Learning "e-Learning" OR "distance learning" OR "distance education"
 OR "online learning" OR "online education" OR "virtual learning" OR "virtual education"

The titles and abstracts of the initial records were screened. Upon removal of duplicate records, 14,171 records remained. Further removal of ineligible records resulted in 3,118 remaining records. Of these records, 2,912 were removed based on the exclusion criteria, and 94 were unavailable for retrieval. The remaining 112 were thoroughly assessed based on the inclusion criteria, and 103 were removed. This process resulted in a total of nine records included in this systematic review.

¹⁰⁸ 5 b) Coding, Data extraction, and Analysis

To extract the data from the studies, a coding process was developed, which included article information (method, sample, and countries of authorship). Study results were also coded based on their relationship with the sub-research questions, which included the technologies used for mathematics e-Learning, changes in practices, educators' perceptions, and students' perceptions. The coding, extraction, and analysis processes were conducted with the NVivo software version 12. Because most of the studies were qualitative in nature, meta-analysis could not be conducted. It should be noted that percentages from the analyses may not amount to 100% due to rounding.

116 **6 III.**

¹¹⁷ 7 Study Characteristics a) Methodological Characteristics

Among the nine studies included in this review, five studies (55.6%) used qualitative methods, two studies (22.2%) used quantitative methods, and two studies (22.2%) used mixed methods. Although the majority of the studies were qualitative, only two out of the nine studies (22.2%) were interpretive in nature, with the rest being descriptive. Almost all studies involved an online survey with the exception of Naidoo (??020

¹²² 8 b) Geographical Characteristics

The studies included in this systematic review encompassed six nations. Three studies (33.3%) took place in 123 124 Indonesia, two (22.2%) in the United States, and one study (11.1%) each for Italy, Rwanda, South Africa, and Ghana. Interestingly, the locations for the studies were mostly clustered around the continent of Africa and the 125 nation of Indonesia. Although Africa has been known to be significantly affected in past pandemics, the Ghanaian 126 and Rwandan governments imposed restrictions promptly, allowing for minimal cases in their respective nations 127 (Attiah, 2020). Contrastingly, South Africa experienced a swift rise in Covid-19 cases early in March 2020 before 128 imposing restrictions (Stiegler & Bouchard, 2020). As such, the findings of the three African studies are reflective 129 of diverse situations albeit being within the same continent. It should also be noted that internet usage is highly 130 limited in Africa, with only 24% of the population having access due to increased costs and poor connectivity, 131 which could be a factor for e-Learning (Tamrat & Teferra, 2020). 132

Indonesia, the nation with the greatest number of studies in this systematic review, was affected by Covid-19 133 early on as well. Reports from June 2020 indicated that Indonesia had the highest number of active cases in 134 Southeast Asia, but at the same time, the lowest number of infection per capita (Olivia et al., 2020). The rise 135 in the number of cases was attributed to the slow response of the Indonesian government when its neighboring 136 countries were already imposing lockdowns (Olivia et al., 2020). Notably, Indonesia was reportedly unprepared 137 for e-Learning as well, with only nine universities having established systems for e-Learning before the pandemic 138 (Siregar et al., 2021). The three Indonesian studies in this review took place in different cities. It should be 139 noted that all Indonesian studies in this systematic review utilized purely qualitative methods, which does not 140 allow for a generalizable view of the nation. 141

Although two studies took place in the United States, the data was still limited as Ludwig's (2021) sample 142 comprised students from a single university in western United States, while Lopez et al.'s (2021) sample only 143 included educators from four higher education institutions in South and Central Texas. Only one study was found 144 in Europe. The single European study was conducted in Italy, a nation that also saw a steep rise of Covid-19 145 cases early in March 2020, and adopted strict measures to contain the outbreak (Saglietto et al., 2020). Although 146 the use of technologies in higher education was not new to Italy at the time of the Covid-19 outbreak, several 147 traditional universities that used blackboard and chalk still existed (Cassibba et al., 2021). No studies that met 148 the criteria were found in South America and Australia. 149

¹⁵⁰ 9 c) Sample Characteristics

The criteria for the study samples in this systematic review included either educators or students in the postsecondary levels. Five studies (55.6%) involved educators, two studies (22.2%) involved undergraduate students, and two studies (22.2%) involved postgraduate students. Notably, the two studies involving postgraduate students both took place in Africa. All three Indonesian studies involved lecturers. Although the North American studies in this review took place in different states of the United States, it is the only continent with a study on educators and on students.

13 RQ3: HOW DID POSTSECONDARY EDUCATORS PERCEIVE MATHEMATICS E-LEARNING DURING THE COVID-19 PANDEMIC?

For the qualitative studies, sample sizes were mostly between 14 to 31, with the exception of Siregar et al. (2021), whose sample included 200 lecturers; however, it should be noted that these 200 lecturers were from a single university, thus also limiting the generalizability of their results. The two quantitative studies had 120 and 467 undergraduate students for their samples, while the mixed methods studies had 27 and 51 professors for their samples. These could be somewhat proportional to the study populations, as the undergraduate student population generally outnumbers the population of educators and postgraduate students. IV.

164 10 Results

11 RQ1: Which technologies were frequently utilized for post secondary mathematics e-Learning during the Covid-19 pan demic?

Seven studies (77.8%) reported on the technologies frequently used for e-Learning during the Covid-19 pandemic (see Table 2). The studies addressing this sub-research question comprised one (14.3%) quantitative, two (28.6%) mixed methods, and four (57.1%) qualitative studies. All studies indicated platforms used or preferred by educators or students. Only one study (Agormedah et al., 2020) reported on the devices used, or lack thereof, for e-Learning, as well as self-reported proficiency for such devices. This unique finding highlighted the challenge of access to technology for e-Learning in Ghana (Agormedah et al., 2020).

Qualitative data regarding the challenges associated with technologies used were presented in three studies 174 Two of these studies indicated lack of training and preparation as major challenges ??Lopez et (33.3%).175 Preferences for and uses of LMS platforms appeared to vary between studies; however, the most frequently 176 cited in this review were Google Classroom (3/7, 42.9%) and Moodle (3/7, 42.9%). Based on the studies in this 177 178 systematic review, Google Classroom appeared to be more popular in Indonesia, while it was only ranked third in 179 Ghana in terms of student awareness ?? Agormedah et In terms of communication platforms, WhatsApp appeared 180 to be the most popular in general, as it was specifically cited in four out of seven (57.1%) of the studies. Notably, WhatsApp was the most preferred or most used communications platform in all of these studies. Only educators 181 (37%) in Cassibba et al.'s (2021) study in Italy reported using mathematical software for e-Learning, and only 182 one educator (7.1%) in Sulistyani et al.'s (2021) study in Indonesia reported using an evaluation software out of 183 184 the seven studies. Although 75% of Lopez et al.'s (2021) participant educators reported giving online quizzes, 185 they did not specify whether these were conducted using an evaluation software.

12 RQ2: What were the changes in educators' practices of teaching postsecondary mathematics during the Covid-19 pandemic?

Changes in educators' practices were reported in only three (33.3%) studies (see Table 3). These studies comprised 189 one (33.3%) qualitative study and two (66.7%) mixed methods studies from different geographical locations. 190 Samples were all educators and the sample sizes ranged from 14 that they had to increase their preparation 191 for e-Learning, used less gestures, and were able to do more with their lessons given the same amount of time 192 because they sent notes prior to each lesson; however, the faster pace was also attributed to the decrease in 193 student interactions. A majority (64%) of Cassibba et al.'s participants, independent of their number of students, 194 had difficulty perceiving whether their students kept up with their lessons. Those who were able to perceive their 195 students' ability to keep up with the lessons mostly had to ask students directly (30%). Notably, practices in 196 terms of language and representations used were mostly retained (Cassibba et al., 2021). In Lopez et al.'s (2021) 197 study in Texas, the changes reported were significant increases in time spent on teaching tasks and on technology 198 usage. 199

13 RQ3: How did postsecondary educators perceive mathemat ics e-Learning during the Covid-19 pandemic?

Four out of the nine studies (44.4%) in this systematic review reported on educators' perceptions regrading mathematics e-Learning (see Table 4). These studies included two (50%) qualitative and two (50%) mixed methods studies. Two studies (50%) took place in Indonesia, one (25%) in Italy, and one (25%) in Texas, United States. Sample sizes varied from 14 to 51.

Educators' perceptions regarding mathematics e-Learning mostly involved challenges in various aspects of e-Learning with a few advantages. Only Irfan et al. (2020) did not report any perceived advantages of mathematics e-Learning. The main advantages identified were improved student involvement (Cassibba et al., 2021;Sulistyani et al., 2021), improved lesson planning (Cassibba et al., 2021), and improved teaching style as well as comfort with technologies (Lopez et al., 2021). More challenges were identified within the studies, as listed in Table 4. Notably, Lopez et al. (??021) reported a significant increase in educators' willingness to teach online.

²¹² 14 Yogyakarta, Indonesia

Advantages: student involvement in learning (92.9%); student involvement in discussions (78.6%) Future Improvements for e-Learning: increased preparation in terms of content and time (71.4%); more varied technology use (50%); more innovative and communicative delivery methods (50%); outcomebased learning adjustments (28.6%); continued focus on deepening student experience (7.1%)

²¹⁷ 15 RQ4: How did postsecondary students perceive mathemat ²¹⁸ ics e-Learning during the Covid-19 pandemic?

Four out of the nine studies (44.4%) in this systematic review addressed this sub-research question regarding students' perceptions of mathematics e-Learning (see Table 5). Three of the studies (75%) were conducted in Africa, while one study (25%) was conducted in Western United States. Two quantitative studies (50%) involved undergraduate students, and two qualitative studies (50%) involved post-graduate students. Sample sizes varied from 20 to 467.

Qualitative findings highlighted both advantages and challenges with mathematics e-Learning. The main advantages perceived by postgraduate students included the ability to revisit lessons, having virtual communities of practice, development of technological skills, improvements in technical problem solving skills, and enhanced communication and research skills (Naidoo, 2020;Nsengimana et al., 2021). The main challenges perceived by post-graduate students included increased costs, lack of internet access, lack of practical and hands-on activities, unclear instructions, limited collaboration, lack of ICT knowledge, insufficient feedback, and distractions and responsibilities at home (Naidoo, 2020;Nsengimana et al., 2021).

Quantitative data for this sub-research question involved the challenges with mathematics e-Learning. The 231 main challenges perceived by undergraduate students were mostly similar to those perceived by postgraduate 232 students with the addition of feeling unprepared for e-Learning, increased anxiety about mathematics e-Learning, 233 and the negative effects of Covid-19 on their mathematics learning abilities (Agormedah et al., 2020;Ludwig, 234 2021). An interesting, albeit non-significant finding by Ludwig (2021) was that students with high anxiety, strong 235 negative perceptions about the effect of Covid-19 on their mathematics learning abilities, and neutral perceptions 236 237 of e-Learning had the lowest midterm scores averaging at 80 points, which was one standard deviation below 238 average. No advantages of mathematics e-Learning were reported in the quantitative studies; however, this may 239 be due to the rigid nature of the instruments used rather than the lack of advantages per se. In Agormedah et al.'s (2020) study in Ghana, a majority (56.7%) of students considered e-Learning to be necessary. 240

²⁴¹ 16 Discussion

242 The findings of this systematic review involved the transitional experiences of postsecondary educators and 243 students regarding mathematics e-Learning during the Covid-19 pandemic in six different countries. The narrow focus on mathematics and the period of the Covid-19 pandemic allowed for a specialized overview of this 244 field during this challenging period, hence the limited number of studies included in the review. The studies 245 were further clustered around certain geographic locations including Indonesia, the United States, and African 246 countries. Nonetheless, the findings from these studies provided a general overview of the technologies used, 247 changes in practices, and perceptions of postsecondary educators and students regarding mathematics e-Learning. 248 ??020) study stated that they wished there were available systems for attendance and assessment, which reflected 249 a lack of awareness regarding such software. Such findings supported the idea that even digital natives may be 250 unprepared for e-Learning as they may only be familiar with technologies for personal use rather than for e-251 252 Learning (Nsengimana et al., 2021). These findings also supported Ahn and Edwin's (2018) idea that specialized software use remains scarce due to difficulties in setup and high costs. As institutions and educators continue 253 to adjust towards e-Learning, it may be helpful to develop more user-friendly and universal software that they 254 could use, and to raise awareness regarding these technologies. 255

In terms of the changes in educators' practices for e-Learning, the main issue appeared to be the increased 256 preparation required for teaching tasks (Cassibba et al., 2021;Lopez et al., 2021). Only Cassibba et al. (2021) 257 reported the use of less gestures, which was purported to be a vital part of mathematics education. The increase 258 in use of technologies reported by Lopez et al. (2021) was unsurprising as it is the main principle of e-Learning 259 (Ayu, 2020). No other major changes in practice and strategies were reported. The finding that a majority of 260 educators in Sulistyani et al.'s (2021) study were able to successfully achieve their goals without major changes 261 shows some promise for the use of e-Learning in mathematics. Cassibba et al.'s (2021) participants likewise 262 263 indicated that they retained the use of natural language, mathematical language, and iconic representations, 264 which is important for the subject of mathematics (Ahn & Edwin, 2018). Although the minimal changes found 265 in this review is promising, educators should also find ways to maximize the benefits of technologies and apply 266 positive changes to their practices and strategies.

Postsecondary educators' perceptions regarding mathematics e-Learning were somewhat mixed, with more challenges reported than benefits. The loss of student interactions and involvement in lessons and discussions appeared to be a major challenge for educators (Cassibba et al., 2021;Irfan et al., 2020;Sulistyani et al., 2021). This challenge supported Neuwirth et al.'s (2020) idea that teaching on a screen with minimal visual feedback can serve as a barrier for student engagement. This challenge also limits the opportunities for student collaboration, which was cited as an important factor for mathematics education (Naidoo, 2020;Nsengimana et al., 2021). Alternatively, the main advantage of e-Learning appeared to be the improvements in student involvement because of their increased responsibilities (Cassibba et al., 2021;Sulistyani et al., 2021). The increase in student responsibilities, however, may be counterproductive for students who are experiencing Covid despair (Ludwig, 2021). As educators in Lopez et al.'s (2021) study indicated work-life balance as a medium-level challenge for

them, educators should also consider the needs of their students during this difficult period.

Relatively more challenges with mathematics e-Learning were reported by students, while only two studies
reported on benefits. The advantage of increased technological, problem solving, communication, and research
skills (Nsengimana et al., 2021) support the idea that students can adjust and progress from digital immigrants
to digital natives (Naidoo, 2020).

Interestingly, a key advantage identified in Naidoo's (2020) study was the creation of virtual communities, 282 which could be a solution to the educators' perceived challenge of loss of student interactions and collaboration 283 (Cassibba et al., 2021;Lopez et al., 2021;Sulistyani et al., 2021). The challenges identified by the postsecondary 284 students supported existing literature indicating lack of readiness for e-Learning (Sakhapov & Absalyamova, 285 2018), possible distractions at home, and other psychosocial factors (Neuwirth et al. 2020). The challenge 286 of family responsibilities may be especially pronounced for postsecondary students who have children (Naidoo, 287 2020). Students should thus be given more time to adjust and training in preparation for e-Learning. Overall, 288 289 mathematics e-Learning may be necessary for the time being and may have benefits, but the multiple challenges 290 identified in this review indicate a need to further develop the field.

²⁹¹ 17 VI.

²⁹² 18 Limitations

A major limitation for this systematic review is the small number of studies that met the criteria. Although 293 this limitation could not be controlled due to the narrow focus of the review, it limits the opportunities 294 for comparison and synthesis. Additional research is needed to provide a more solid evidence regarding the 295 transitional experiences of postsecondary educators and students for mathematics e-Learning during the Covid-296 297 19 pandemic. Notable geographical limitations were also found in this systematic review, with most studies 298 clustering in Africa and Indonesia. Similar studies in other nations, especially in South America and Australia would be particularly helpful in providing a more diverse and global view of the field. More quantitative evidence 299 with larger sample sizes would also be beneficial to obtain a more holistic overview of the transitional experiences 300 of educators and students regarding postsecondary mathematics e-Learning during the Covid-19 pandemic. 301

¹Postsecondary Mathematics during the Covid-19 Pandemic: A Systematic Review



Figure 1: RQ1:

1

Topic

Search terms

Figure 2: Table 1 :

Figure 3:

$\mathbf{2}$

Author (Year)	MethodSample	Location	Results	
Agorme	Quhantitk07ve	Cape Coast	Awareness of platforms: Alison $(202/467, 43.3\%)$; Moodle	
al. (2020)	survey under-graduate	Ghana	(132/467, 28.3%); Google Classroom $(125/467, 26.8%)$	
()	students		Preference for e-Learning: WhatsApp (236/467, 50.5%);	
			Google Meeting $(85/467, 18.2\%)$; Zoom $(82/267, 17.6\%)$	
			Devices used for e-Learning: smartphones $(358/467, 76.7\%)$; laptops $(40/467, 8.6\%)$; no device $(62/467, 13.3\%)$	
			Device proficiency for e-Learning: smartphones	
			(186/467, 39.8%); laptops $(161/467, 34.5%);$ uncertain $(106/467, 22.7%)$	
CassibbaMixed 27 et al		Sicily, Italy	Most frequently used: Microsoft teams (100%); writing	
(2021)	Methods ducators sur- vev		tablets (61%); mathematical software (e.g. Mathematica;	
			37%)	
Irfan et al.	Qualita 26 ve Sumatra,	Java,	Most used platforms: Google Classroom (32%); Zoom	
(2020)	survey educators	Kaliman- tan,	(24%); Edmodo (24%); Skype (8%); university LMS (8%)	
		and	Challenges	rep an
		Sulawesi,	programming (Adobe Flash and web design), and video	
		Indonesia	editing	

Figure 4: Table 2 :

Author Metho S ampleocation (Year)	Results
Cassibb Mixed 27 Sicily, Italy Ch et al.	anges with e-Learning: increased preparation; less
(2021) metho ds lucators survey	gestures; pre-sent notes; lack of student interaction; unable to perceive whether students kept up with lessons Retained: use of natural language, mathematical lan- guage, and iconic representations
Lopez Mixed 51 Texas, U.S. Ho et al	ours increased: educators with one or two courses from
(2021) metho ds lucators survey	11.4 to 17.3 hours per week (52% increase); educators with three or more courses from 28.5 to 38.9 hours per week (36% increase) Technology usage: youngest group (aged 24 to 39 years) from 2.8 to 5.5 (96% increase); middle group (aged 40 to 54 years) from 3 to 5.6 (87% increase); oldest group (aged 55 years and above) from 3 to 5 (67% increase), all significant at (p < 0.0001)
	Figure 5: Table 3 :

$\mathbf{4}$

Author (Veen)	MethodSan	Results			
(Tear) Cassibb et al.	aMixed 27	Sicily, Italy	Advantages of e-Learning: improved student		
(2021)	methodæducators survey		involvement responsibility: improved lesson planning Challenges:	becaussé	increased
	U		loss of human exchange (43%) ; loss of student interactions (27%)		
Irfan et al	Qualitat 26 e	Sumat Java	raChallenges: limited delivery methods because of lack of		
(2020)	survey edu	ica Kas ima tan	anspecial software for mathematics; difficulty monitoring		
		and Su-	students' struggles		
		lawesi, Indone	sia		
Lopez et al.	Mixed 51	Texas, U.S.	Advantages: increased comfort level with technologies		
(2021)	methodæducators survey		(69%); improved teaching style (55%) Top Challenges (out of 102 points): testing (83); encouraging student interactions with each other (81) Medium Level Challenges: absenteeism (63); personal teaching styles (61); student connectivity (58); work-life balance (53); time management (48); remote office hours (44) Low Level	professor	-student in
			Challenges: whiteboard use (39); homework (38); educator connectivity (32); LMS (16) Willingness to teach online: significant increase from 5 (10%) to 19 (37%) educators ($p < 0.0005$)		
Sulistya et al.	nQualitat∎≰e				
(2021) descrip educators tive		lcators			

Figure 6: Table 4 :

$\mathbf{5}$

Authornal Author	Results
Agorn@cdaht#67 Cape et tative al	Challenges: access to continuous internet connection (55.5%
(2020)surveyunder- Coast,	had no access, 29.8% were unsure); finances for internet data
gradua & hana students	(67.9% could not afford enough data, 23,1% were unsure); unfamiliarity with e-Learning (86.7% were unfamiliar, 91.9% used e-Learning for the first time); preparation for e-Learning (47.5% felt unprepared, 19.9% were unsure) Perception of e-Learning: 56.7% considered it necessary, 43.3% did not consider it necessary
Ludwiguantit20 ive Western (2021) survey under-United	Challenges: anxiety about mathematics e-Learning (mean $6.3/10$); Covid-19 effects on mathematics learning ability (mean
gradua&tates students	4/10) Perception of e-Learning: neutral (mean 4.7/10) Non- significant Correlations: students with high anxiety levels scored 6.2 points (0.4 standard deviations) below average in midterm exams (not significant); students with high anxiety, strong negative perceptions about Covid-19 effects on mathematics learning ability, and neutral perception of e-Learning scored lowest in midterm exams (80 points, 1 standard deviation below average, not significant)
NaidoQualit 3t ive KwaZulu- post-	Advantages: ability to revisit lessons with asynchronous
(2020)nter- graduaNatal, pretivist	recordings and resources; creation of virtual communities of
studen S outh Africa	practice for collaboration and online social support Challenges: device, data, and resource costs; family responsibilities and distractions at home
Nseng Qmailia20 ive Kigali, et post- al.	Advantages: improved technological skills; improved technical
(2021)nter- gradua Rewanda pretivist	problem solving; enhanced communication and research skills
students V.	Challenges: lack of internet access; lack of practical works or simulations; unclear instructions for online exercises; limited collaboration; lack of resources; lack of hands-on activities; lack of access to laboratories and field trips; lack of knowledge on ICT tools; insufficient feedback; distractions at home

Figure 7: Table 5 :

Figure 8:

18 LIMITATIONS

³⁰² .1 Availability of Data and Materials

³⁰³ The dataset for this article were derived from peer-reviewed scientific publications, which are listed as references.

304 .2 Competing Interests

³⁰⁵ The author declares that they have no competing interests Funding This review received no external funding VII.

306 .3 List of Abbreviations

- [Attiah (2020)] 'Africa has defied the covid-19 nightmare scenarios. We shouldn't be surprised'. K Attiah .
 https://www.washingtonpost.com/ The Washington Post 2020. September 22.
- [Ahn and Edwin ()] An e-Learning model for teaching mathematics on an open source learning platform.
 International review of research in open and distributed learning, J Y Ahn , A Edwin . https://
 www.erudit.org/en/journals/irrodl/1900-v1-n1-irrodl04235/1055557ar/abstract/ 2018.
 p. 19.

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