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The Effects of Covid-19 on Science Education: A Thematic Review of International Research.

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ABSTRACT
The health emergency caused by the COVID-19 pandemic has transformed and decisively affected the entire education system, which has resulted in an urgent need to adapt it to an online scenario. Science education is an area that has been highly affected by and, as a consequence, science teachers were forced to make an extra effort to create virtual learning environments accessible for all students. This study offers a systematic review to synthesize how the COVID-19 pandemic has influenced science teachers' educational practices and adaptations. To this end, *Web of Science*, ERIC and Scopus databases used to explore the virtual educational practices, e.g., teaching-learning processes, during the pandemic. The purpose of this study is to analyze the main bibliographic characteristics of the collected literature (research purpose, methodological design, geographical and temporal distribution, central themes) via thematic analysis. The findings offered a synthesis of studies that explain innovative practices, tools, and strategies that were very useful for teachers and students in the STEM area. We believe that future lines of research should be oriented towards broadening the analysis of different pedagogical approaches developed in the teaching of STEM areas during the health crisis by COVID-19. This could be useful for guiding professional and educational actions.

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Introduction

The COVID-19 pandemic has had a major impact on different sectors of society. Its rapid contagiousness, together with the high mortality associated with it, has caused an unprecedented health emergency. Faced with this situation, the different governments in the world have applied a series of measures based on the principle of social distancing with the main objective of safeguarding public health. In the particular case of the education sector, these measures had a decisive impact on it by leading to the total closure of teaching establishments regardless of the stage of education (Arroio, 2020; Murphy, 2020). As a result, there has been a rapid and "forced" transition from face-to-face to distance,

digital, and online learning (Carrillo and Assunçao, 2020). This shift was faced with many challenges, such as poor teacher training or lack of resources in both schools and home environments (Huber and Helm, 2020; Zhang et al. 2020). Despite this shift, educational institutions in general, as well as teachers, students, and families in particular, have made an enormous effort to adapt to this virtual scenario (Morgan, 2020).

This "online" educational practice had been in use since the beginning of the century with the expansion of the internet and the arrival of new technologies (Rodriguesa et al., 2019). Thus, for example, we found universities that were already fully virtual before the pandemic; or even other educational sectors that employed distance education and the use of digital media as ways to complement face-to-face teaching-learning activities (Gamage et al., 2020; Murphy, 2020). However, despite the numerous benefits reported in the books on this type of teaching (Gashi, 2020), these practices were not widespread, let alone standardized across the education sector. For this reason, some authors refer to this forced transition caused by COVID-19 as emergency distance learning (Bozkurt and Sharma, 2020).

Amidst this situation, numerous studies have focused on analyzing how different educational sectors have faced with this emergency by analyzing aspects such as changes in practices, adaptations used, innovation experiences carried out, challenges, obstacles, and benefits encountered, etc. (Bao 2020; Ferdig et al., 2020; Huber and Helm, 2020; Flores and Gago 2020; Quezada, Talbot and Quezada-Parker 2020; Zhang et al. 2020).

These studies have highlighted how, out of the three fundamental pillars of education (knowing how to know, knowing how to do, and knowing how to be), COVID-19 has hit and weakened two of them in particular (Millán, 2020). Whereas numerous studies indeed enhance the success of this emergency distance learning in aspects related to knowing how to know, that is, in aspects such as the transmission of knowledge, the sending of materials, or the supervision of different aspects of the teaching-learning process, among other elements (Gemage et al., 2020), others emphasize the limitations of this type of educational practices in the development of skills related to knowing how to do and knowing how to be (Novak and Kravanja, 2020; Gemage et al, 2020; Millán, 2020).

In this sense, the areas of Science, Technology, Engineering, Mathematics (STEM) and Science Education have been particularly affected by this exceptional situation due to the large number of practical skills associated with them (Novak and Kravanja, 2020). COVID-19 and the new situation of distance education have hindered the development of practical skills by preventing direct contact with learning experiences or with materials and objects that are determinant for teaching and learning in these areas (Sithole et al, 2016; Cortner et al. 2017).

In this situation, there is a need to analyze how the STEM and science education areas are dealing with this problem, as well as whether the strategies developed are managing to provide quality educational experiences that enable the educational objectives of the areas to be achieved. Therefore, this paper consists of a systematic literature review that aims to compile the most relevant information published in the international literature on educational practices and adaptations developed in the areas of STEM and science education during the pandemic. To this end, the aim is to answer the following research questions:

- What are the main characteristics of the studies analyzed (geographical distribution, temporal evolution, methodology, and purposes)?
- What practices have the STEM and science education areas used during the pandemic?
- What challenges, obstacles or experiences have STEM and science education books highlighted?

In order to answer these questions, firstly, an intensive systematic search of the scientific literature on this field of study was conducted. Subsequently, a topographical and thematic analysis of the results was carried out (Braun and Clarke, 2006; Ültay and Çalik, 2011), which has allowed us to obtain a general overview. Finally, suggestions and future lines of research were highlighted.

Methods

The present research consists of a systematic review using the PRISMA Statement (Moher et al., 2009). This type of review aims to obtain the highest possible degree of robustness and quality of research by maximizing the systematization of the search, evaluation, and synthesis of results (Grant and Both, 2009; Booth, Papioannou and Sutton, 2016; Deveci and Çepni, 2017; Ulger and Çepni, 2020; Ormanci, 2020). In this case, an international systematic review of STEM and science education practices during the COVID-19 pandemic was conducted.

A) Data collection

Three different databases were used for this systematic review. On the one hand, two were selected for their international importance, that is, *Web of Science* (*WoS*) and *Scopus*. On the other hand, the *Education Resources Information Centre* (*ERIC*) database was selected for its relevance in the field of education.

The keywords selected were *STEM* and *science education*. In addition, different synonyms were used for *distance learning*, such as online learning, virtual learning, remote learning, e-learning, digital learning; and also terms related to *Covid-19* like COVID-19, coronavirus, pandemic, etc. Although the synonyms used for distance learning are slightly different, it was decided to use them in the search as they were considered relevant to the research objective. Finally, these terms were combined to form different search equations.

On the other hand, inclusion and exclusion criteria were also determined (see Table 1), for which both pragmatic (appropriateness to the research objectives) and quality criteria were taken into account (Codina, 2018; Booth, Panpainnou and Suttton, 2012).

Table 1

Selection Criteria

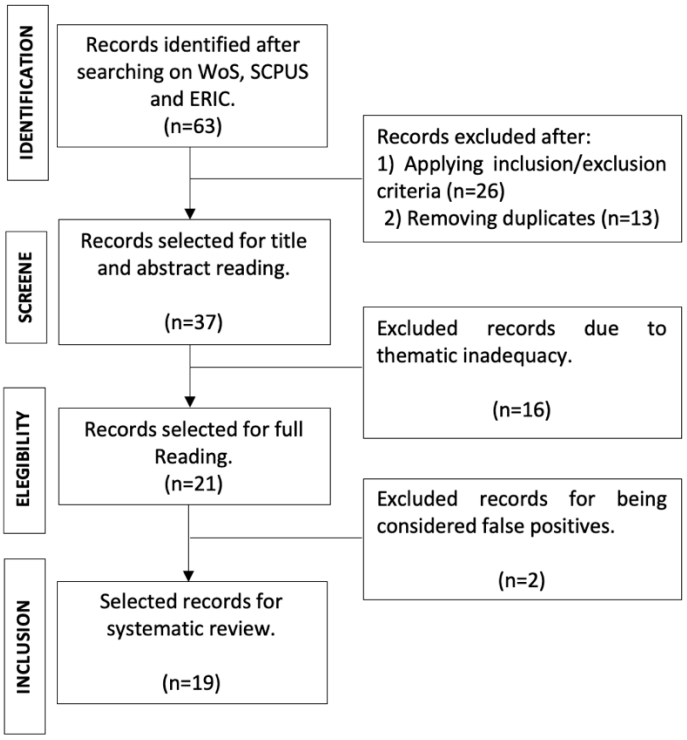
Inclusion criteria	Exclusion Criteria
- Studies resulting from the search equation. - Scientific studies published in article format. - Scientific studies were published during the pandemic period. - Relevant studies that answered the research questions.	- Studies that do not present thematic adequacy with our purpose of the study. - Studies that do not meet quality criteria - Studies that do not meet the inclusion criteria.

B) Search Process

According to the search equations, a total of 63 papers were obtained, being reduced to 37 after the application of the inclusion and exclusion criteria (n: 26) and the elimination of duplicates (n: 13). The remaining 37 papers were subjected to a two-fold evaluation. Firstly, a title and abstract reading were carried out in which those documents not directly related to our study objective were eliminated (n: 16). Secondly, a complete reading of the rest of the documents was carried out in search of false positives (Codina, 2018). Two documents were discarded from this second phase. Figure 1 shows the different phases of the study selection and exclusion process. This entire evaluation and selection process was carried out by four different researchers to provide the highest degree of quality, coherence, and robustness to the research. In the end, 19 papers were selected for review.

Figure 1

Systematic review flowchart



Source: Own elaboration.

C) Data analysis

For the analysis of the selected documents, two distinct processes were carried out. Firstly, a descriptive analysis of the results was performed, for which an information gathering matrix was drawn up. This matrix made it possible to collect and synthesize the most relevant information from each study concerning the date of publication, research objectives, methodology, data collection tools, sample characteristics, results, main contributions to future lines of research.

Secondly, a thematic analysis (Braun and Clarke, 2006) was carried out using the qualitative software *Nvivo 12™*. This analysis allowed us to organize the results into major emerging thematic areas. The selection and organization of these thematic foci was performed by consensus among the four researchers based on individual readings and reflections.

D) Realibity of the Study

The use of databases such as WoS and Scopus provides a high level of reliability by indexing only peer-reviewed publications. On the other hand, the search, selection, and analysis process was carried out at all times through processes agreed upon by all the researchers. This provides a greater degree of reliability and precision to the research, as each aspect of the search and analysis process was agreed upon after a process of individual reflection and debate. In addition, in terms of research ethics, a double-checking process was also employed (Creswell, 1998), in which a researcher other than the research authors supervised the entire process in order to minimize potential harm by checking the credibility of codifications. Finally, a high inter-rater co-efficient (0.94) was obtained (Miles and Huberman, 1994).

E) Limitations of the Study

We ought to highlight several limitations included in this systematic review. The use of filters and the databases selected may cause bias, which may lead to the non-consideration of documents that could be of interest, such as some grey literature or documents that have not undergone peer-reviewed processes. However, all these decisions were made to obtain the maximum scientific rigor.

Findings

This section presents the main findings obtained. The first part shows the general topographical characteristics of the results obtained, and the second part analyzes the characteristics of the content and thematic focuses of the articles analyzed.

General Bibliometric Characteristics of the Pubications

Table 2 shows the general characteristics of the studies included in the systematic review. As this topic predates the current pandemic situation caused by the coronavirus disease, all the included studies were conducted during the year 2020. Articles are recorded from May 2020, and it was noted that most of the studies were conducted in August 2020. In terms of the number of authors, studies with more than three authors are much more frequent compared to those with three, two, and one author. In addition, the type of publication analyzed corresponds to scientific research articles.

Table 2

General Characteristics of the Studies Analyzed

	Codes	f
Year of publication	2020	18
Months of publication	May	2
	June	1
	July	1
	August	8
	September	4
	October	1
	November	1
Number of authors	1	4
	2	3
	3	1
	+3	10
Type of publication	Articles	18

Source: Prepared by the authors.

Table 3 shows the geographical distribution of the articles analyzed. Our results reveal that the United States is the country with the highest scientific production in the subject analyzed. It is followed, although to a lesser extent, by other countries such as Spain, Canada, and England. All the articles that were finally included in this research are written in English.

Table 3

Distribution of studies according to geography

Country	f	Studies
USA	9	Armstrong-Mensah, et al. (2020)
		Bopegedera (2020)
		D'Souza, et al. (2020)
		Hughes, et al. (2020)
		Hwang (2020)
		Mahaffey (2020)
		Perets, et al. (2020)
		Ray and Srivastava (2020)
		Van Nuland and Langley (2020)
SPAIN	2	Barra, et al. (2020)
		Novak-Pintarič and Kravanja (2020)
CANADA	2	Hughes, et al. (2020)
		Code, Ralph and Forde (2020)
ENGLAND	2	Gamage, et al. (2020)
		Longhurst, et al. (2020)
PHILIPPINES	1	Dolino (2020)
SCOTLAND	1	Gamage, et al. (2020)
SRI LANKA	1	Gamage, et al. (2020)
MALAYSIA	1	Kamal, et al. (2020)
IRELAND	1	Longhurst, et al. (2020)
ITALY	1	Novak-Pintarič and Kravanja (2020)
JAPAN	1	Novak-Pintarič and Kravanja (2020)
CHINA	1	Novak-Pintarič and Kravanja (2020)
RUSSIA	1	Novak-Pintarič and Kravanja (2020)
SERBIA	1	Bojović, et al. (2020)
BRAZIL	1	Silva, et al. (2020)

Source: Prepared by the authors.

An analysis was made of the different branches of science covered by the studies reviewed. This analysis, shown in table 4, shows the distribution of the studies according to the sciences studied. In this case, the health sciences are the most frequently used in this type of research.

Table 4

Distribution of studies according to the fields of science being studied

Research fields	Studies	f
- Computer science education	Bojović, et al, (2020);	
- Physical Chemistry	Bopegedera, (2020)	
- 68 different STEM degrees: Biology, Biological Chemistry, Environmental Science, Environmental Policy, Mathematics and Computer Science	D'Souza, et al., (2020)	5
- Chemistry	Dolino, (2020)	

-	Undergraduate chemistry course	Perets, et al., (2020)	
-	Public Health	Armstrong-Mensah, et al., (2020)	8
-	Zoology, ethology	Hughes, et al., (2020)	
-	Chemistry subject in forensic science degree	Hwang, (2020)	
-	Pre-university level Physical Sciences, Life Sciences.	Kamal, et al., (2020)	
-	Anatomy	Longhurst, et al., (2020)	
-	Health sciences	Mahaffey, (2020)	
-	Health sciences, dentistry	Silva, et al., (2020);	
-	Biomedical sciences	Van Nuland, Hall and Langley, (2020)	
-	Educational Technology	Bojović, et al., (2020)	2
-	Science education	Ray and Srivastava, (2020)	
-	Telecommunications	Barra, et al., (2020)	3
-	Engineering	Gamage, et al., (2020)	
-	Chemical engineering	Novak-Pintarič and Kravanja, (2020)	

Source: Prepared by the authors.

When the purposes of the studies are examined, it appears that a large number of studies aim to determine adaptations, practices and strategies in the changing scenario brought about by COVID-19. (f: 10). On the other hand, some research emphasizes the importance of distance or online learning and its impact on students and their academic performance (f: 5). Finally, several studies that point to the models adopted and their impacts on the transition to e-learning (f: 3). In addition, Table 5 shows the distribution of studies in terms of the methods used to meet these proposed objectives.

Table 5

Distribution of studies according to research purposes

Themes	Purpose	Studies	f
Distance learning and its impact on students.	To explore the challenges and potentials encountered by students about distance learning-	Armstrong-Mensah, et al., (2020)	5
	To analyze the degree of participation and engagement in online education	Hwang, (2020)	
	To study students' perceptions of the sudden shift towards online learning in terms of participation and assessment	Kamal, et al., (2020)	
	To examine the main issues and projections regarding the impact of the coronavirus crisis on student performance indicators	Novak-Pintarič and Kravanja, (2020)	

	To describe learning and teaching experiences of students and instructors	Perets, et al., (2020)	
Adaptations, practices and strategies in the changing scenario	To describe the adaptation developed from COVID-19 in the evaluation model in a university programming course	Barra, et al., (2020)	
	To offer the different practices developed in this course during the pandemic and to analyze their suitability for student learning	Bopegedera, (2020)	
	To study the engagement strategies of educational technology teachers to cope with the transition from a face-to-face to a virtual scenario due to the COVID-19 health crisis	Code, Ralph and Forde, (2020)	
	To analyze the different strategies used to work on scientific writing with the arrival of COVID-19 and distance learning	Dolino, (2020)	
	To analyze different strategies for approaching online teaching of engineering practices with the arrival of covid-19	Gamage, et al., (2020)	
	To propose alternatives for the online teaching of zoology and ethology	Hughes, et al., (2020)	
	To identify approaches adopted in the UK and the Republic of Ireland to deliver anatomy education through online means	Longhurst, et al., (2020)	10
	To connect "real life" scenarios with chemistry concepts in an online chemistry laboratory course for health science students	Mahaffey, (2020)	
	To propose virtual classes and online resources as a more effective and alternative way to learn science from home	Ray and Srivastava, (2020)	
	To highlight key principles and questions for educators to consider when selecting and integrating e-learning tools into curricula	Van Nuland, Hall and Langley, (2020)	
Models and impacts in the transition to e-learning	To propose a model to facilitate the transition from traditional to e-learning	Bojović, et al., (2020)	
	To analyze the impact of the transition to online learning on students and teachers of STEM disciplines where the practical part is of great importance	D'Souza, et al., (2020)	
	To evaluate the effect of distance education (DE) activities implemented due to social isolation on the quality of life of undergraduate dental students	Silva, et al., (2020)	3

Source: Prepared by the authors.

Thus, when examining table 6, it was observed that half of the studies analyzed used methods other than qualitative and quantitative (9), of which 6 based their research on theoretical reviews and systematic literature reviews, and 4 used mixed methods (qualitative-quantitative). Secondly, quantitative methods were used, mainly cross-sectional studies and surveys (5). Finally, 4 studies

preferred qualitative methods through case studies, qualitative open-ended questions, thematic analysis, and qualitative survey analysis (4).

Table 6

Distribution of studies according to the methods used

Research approach	Methods	Studies	f	Total
Quantitative research	Transversal study	Armstrong-Mensah, et al., (2020); Silva, et al., (2020)	2	
	Survey research	Bopegedera, (2020); Hwang, 2020; Kamal, et al., (2020)	3	5
Qualitative research	Case study	Barra, et al., (2020)	1	
	Stated that only qualitative research	Code, Ralph and Forde, (2020); Mahaffey, (2020); Perets, et al., (2020)	3	4
Others	Mixed study (qualitative/quantitative)	Bojović, et al., 2020; D'Souza, et al., (2020); Longhurst, et al., (2020)	3	
	Theoretical research/literature review	Dolino, (2020); Gamage, et al., (2020); Hughes, et al., (2020); Novak-Pintarič and Kravanja, (2020); Ray and Srivastava; (2020); Van Nuland, Hall and Langley, (2020)	6	9

Source: Prepared by the authors.

In terms of the data collection tools, Table 7 illustrates the distribution of the studies. The researchers preferred online surveys for data collection (f: 4), followed by the collection of information through online questionnaires (f: 2). In the rest of the research analyzed, some researchers used other types of tools, such as paper questionnaires, google forms; others used participant observation; others did not specify them. The studies are shown below according to the preferred study participants.

Table 7

Distribution of the studies according to data collection tools

Tools for data collection	Studies	f
Online questionnaire	Armstrong-Mensah, et al (2020); Bopegedera (2020)	2
Participant observation	Barra, et al. (2020)	1

Online survey	Code, Ralph and Forde (2020); D'Souza, et al. (2020); Mahaffey (2020); Perets, et al. (2020)	4
Documents/archives/studies	Gamage, et al. (2020)	1
Video viewing	Hwang (2020)	1
Lickert scale	Kamal, et al. (2020)	1
Questionnaire	Bojović, et al. (2020)	1
Google Forms	Silva, et al. (2020)	1
Not specified	Dolino (2020); Hughes, et al. (2020); Longhurst, et al. (2020); Novak-Pintarič and Kravanja (2020); Ray and Srivastava (2020); Van Nuland, Hall and Langley (2020)	6

Source: Prepared by the authors.

Table 8 reflects the fact that practically all the studies preferred to analyze students (f: 15), among which university students stand out, followed by secondary school students (f: 13), though to a lesser extent (f: 2). There are no articles that pay attention to students in primary and early childhood education. In addition, it was noted that other research preferred to examine university teachers as a sample (f: 4). Finally, there are three articles in which the participants in their studies are not identified as either theoretical or thematic reviews of the literature.

Table 8

Distribution of studies according to participants in included studies

Participants		**f**	**Total**
Student	University	13	15
	High school students	2	
Teacher	University	4	4
Unspecified		3	3

Source: Prepared by the authors.

Strategies used to Address the Pandemic

This section provides a thematic analysis of the results, suggestions, and recommendations of the studies analyzed. From this analysis, strategies are extracted in the form of suggestions for betterment in order to improve educational processes in unforeseen situations such as those caused by COVID-19. The following table shows the distribution of the studies according to the recommendations, suggestions, and results obtained.

Table 9 shows that the vast majority of the suggestions refer to the development of pedagogical practices (f: 12). We also find suggestions related to the need for virtualization of teaching in the face of possible scenarios, such as those that have occurred (f: 7), together with suggestions on the exploitation and use of technological and virtual tools (f: 6). On the other hand, there are also suggestions related to the forms and improvements in assessment and marking (f: 6). Finally, a smaller number of suggestions were made regarding teacher training (f: 4).

Table 9

Distribution of suggestions

Themes	***Main Suggestions***	***Studies***
Suggestions for developing the evaluation of teaching-learning processes (6)	More flexible approach in the process of assessing science practice	Longhurst, et al., (2020)
	Further discussions to facilitate decisions by higher education institutions concerning curriculum adaptation and assessment methods	
	Need to strengthen academic integrity and build self-confidence to participate in online knowledge tests in a fair and non-fraudulent manner	Novak-Pintarič and Kravanja, (2020)
	Prioritize classroom activities and assessments that are more tolerant of the absence of a physical classroom	Armstrong-Mensah, et al., (2020)
	Recognize that a universal pass/fail grading system can negatively affect student participation	Perets, et al., (2020)
	Encourage formative evaluations that are sustained over time and accompanied by more constant feedback. To this end, there is a need to develop new assessment strategies in an online format	(Hwang, 2020)
Suggestions of the need for virtualization (7)	There is a need to improve reliable technology	Armstrong-Mensah, et al., (2020)
	Need to improve virtual teaching conditions and response times to student correspondence	
	Take into account experiences towards the transition to online teaching, to improve aspects for the future of education	Kamal, et al., (2020)
	Ensure student access to online resources	(Gamage, et al., 2020)
	Establish a "guiding principle of continuity of teaching and learning" as soon as possible	Perets, et al., (2020)
	Implement a semi-mandatory attendance policy for classes, teaching partners, and peer tutor sections to increase course structure and retain student participation, while practicing empathetic instruction for individual student situations	
	Introduce virtual laboratories	Gamage, et al., (2020); Novak-Pintarič and Kravanja, (2020); Ray and Srivastava, (2020)

Suggestions for teacher training (4)	Greater speed and effectiveness in the educational response to situations such as the health emergency that has occurred. To this end, improved virtual platforms are essential, as is the process of familiarisation and mastery of this type of teaching	Bojović, et al., (2020)
	Teacher training for online teaching	Armstrong-Mensah, et al., (2020)
	Provide specialized training in online instruction for all trainers, including peer tutors	Perets, et al., (2020)
	Use of increased peer learning by teachers, both within the school and through existing professional networks	
Suggestions on the use of technological and virtual tools (6)	Creation of more tools such as autocorrection that seek more direct and specific feedback and communication with students	Barra, et al., (2020)
	Carrying out distance education activities through devices with teacher-student interaction is a key tool for dealing with the situation	Silva, et al., (2020)
	Invest efforts and resources in the virtualization of our daily science education courses in the academic environment	Ray and Srivastava, (2020)
	Develop in-depth simulation tools for inverse experiential learning	Gamage, et al., (2020)
	Introduction of advanced communication tools for distance learning, which could continue to be used after the epidemic	Novak-Pintarič and Kravanja, (2020)
	Use of the LTW (learning to write) method for teaching writing in chemistry	Dolino, (2020)
Pedagogical suggestions (12)	Consideration of students' course work overload	Armstrong-Mensah, et al., (2020)
	Achieving attractive content for synchronous classes	
	Pedagogical practices implemented online that are interesting to develop in other STEM courses and fields	(Bopegedera, 2020)
	Increase student participation (e.g., increased use of "meeting rooms" and group work)	Perets, et al., (2020)
	Increasing the frequency of feedback given to students	
	Creating opportunities for asynchronous learning (e.g., posting recordings of lectures)	
	Encouraging the transition to student-centered learning	Code, Ralph, and Forde, (2020); D'Souza, et al., (2020); Novak-Pintarič and

	Kravanja, (2020)
Introduce even more computer science topics into the chemistry and chemical engineering curricula	Novak-Pintarič and Kravanja, (2020)
Online education, it should promote ways for students to reflect on their work and efforts and to have the opportunity to correct mistakes. Specific strategies include: Encouraging positive online interactions by providing students with a voice	Dolino, (2020)
Providing practical, personalized, and positive feedback	Bojović, et al., (2020); Dolino, (2020); Hwang, (2020)
Encouraging co-evaluation among peers, to foster motivation	Dolino, (2020)
Importance of (anonymous) feedback from students on these online practices in order to improve them	Hughes, et al., (2020)

Source: Prepared by the authors.

Discussion and Conclusions

Concerning the characteristics of the publication on our object of study, it is important to highlight that most of the studies were conducted in the months of August-September 2020. Since the closure of educational centers due to the health crisis took place approximately in March, it is coherent that publications related to teaching practices and strategies gave results several months later. The first studies began to emerge in May, and from that month onwards the body of publications on this topic has increased.

The findings show that, on most occasions, the studies were led by research groups of more than three authors. On a few occasions, the studies were carried out by only one or two researchers, and in those cases, they coincided in being theoretical or literature review articles. Regarding the geographical distribution of the selected scientific production, it is essential to highlight its heterogeneity. Thus, 15 different countries developed this line of research. This could be motivated by the fact that "transforming" educational practices to an online scenario was a priority in almost all parts of the world, so it was a common and global issue. However, our analysis notes the predominant scientific production in the USA (Armstrong-Mensah, et al., 2020; Bopegedera, 2020; D'Souza, et al., 2020; Hughes, et al., 2020; Hwang, 2020, Mahaffey, 2020, Perets, et al., 2020, Ray and Srivastava, 2020, Van Nuland and Langley, 2020).

In terms of the most predominant disciplines of selected scientific studies(in the STEM and science education fields) are the Health Sciences. Health sciences education was one of the fields that has been most affected in terms of the conversion to an online teaching scenario (Rose, 2020; Toquero, 2020). This is so because, in fields such as telecommunication or computer science, e-learning did not require significant changes to develop further. However, those areas of education where face-to-face presence was essential for the implementation of skills and competencies required greater effort and commitment to transform their educational practices into the new digital scenario (Jandrić et al. 2020).

Regarding the research purposes of the studies included in this review, it is important to highlight that all of them aimed to contribute to the knowledge of educational practices and strategies

carried out throughout the health crisis by COVID-19 in the area of science education. Within this general-purpose, some of them aimed to analyze the impact of this situation on students' learning (D'Souza, et al., 2020; Hwang, 2020; Kamal, et al., 2020; Ray and Srivastava, 2020; Silva, et al., 2020; Van Nuland, Hall and Langley, 2020). As it can be seen from the findings (Table 9), the pandemic has caused many complex scenarios for teachers in the area of science education and, in this sense, analyzing its impact is an emerging and priority topic of study to guide new ways of teaching practice. A predominant body of research has aimed to expose those didactic and educational adaptations developed in the virtual teaching transition (Bopegedera, 2020; Code, Ralph, and Forde, 2020; Hughes, et al., 2020; Mahaffey, 2020; Perets, et al. 2020).

Selected studies in this review expose practices, tools, and strategies that are truly innovative and could be of great use to practicing teachers and future education professionals in situations of complexity and/or virtuality such as the one that occurred (Silva, et al.,2020; Perets, et al., 2020; Mahaffey, 2020). Other publications have also focused on the development of models of transition to a virtual educational scenario and the evaluation of their impact (Armstrong-Mensah, et al., 2020; Barra, et al., 2020; Bojović, et al., 2020). In this way, the establishment of guiding frameworks for teacher intervention could be the key to teaching in areas such as STEM or science education.

In the analysis of the methodological designs used in the included studies, it can be appreciated that the literature review or theoretical research approach was the most commonly used. This may be since it is still too early to obtain sufficient evidence or empirical results on the repercussions or impact of the pandemic on educational practices in the area of science education. This is why many researchers have had to address such questions from a theoretical or epistemological approach. However, there are also studies that have been able to delve into this issue from a more practical perspective (Barra, et al., 2020; Bopegedera, 2020; Mahaffey, 2020) or have analyzed, through questionnaires, the perceptions of teachers and/or students about virtual teaching in times of pandemic (Armstrong-Mensah, et al, 2020, Bojović, et al., 2020), Barra, et al., 2020, Bopegedera, 2020; Code, Ralph, and Forde, 2020; D'Souza, et al., 2020; Kamal, et al., 2020; Longhurst, et al., 2020; Silva, et al., 2020). Therefore, the views/opinions of educational professionals and students on the practices and strategies developed are of great value to researchers in assessing the impact of Covid-19 on science education (Bubb and Jones, 2020).

In terms of the methodology developed in these studies, online surveys are the predominant tool for developing this type of research. As Evans and Mathur (2005) argue, online surveys are a potential resource for obtaining relevant information on a specific topic, especially when face-to-face data collection is unlikely or difficult. In this way, this tool makes it possible to collect information from a large number of people without the need for geographical proximity. At the same time, because of its characteristics, it is capable of collecting heterogeneous and wide-ranging information on a subject under study.

In our presented findings, the participants of the studies concentrate on university or high school students or teachers. This was one of our requirements when structuring the systematic review. However, within this specific population, students were more numerous than teachers when it came to framing research. This is consistent with methodological approaches that emphasize the students' voice in the assessment and study of their teaching-learning process (Gunter and Thomson, 2007). At the same time, within the student sample sector, university students in the area of science education were the most common in the studies included in this literature review.

With regard to the analysis of the findings presented in the selected studies, it is important to point out that, for a better understanding, we structured it into five main emerging themes. These five themes deal with strategies used in the virtual teaching of science education and are linked to the need for virtualization in teaching due to the COVID-19 crisis: better teacher training in digital literacy and training in new educational technologies, the use of virtual tools for teaching performance, pedagogical suggestions, and how to evaluate in times of virtual teaching in areas such as STEM and science education. The COVID-19 crisis has dismantled a series of deficits that education has been carrying for several years (Nash, 2020). Despite the rise of new technologies in education, many educational

institutions, even at higher levels, have been deeply rooted in traditional teaching models, making the transition to a fully online scenario an even more impactful change (Tejedor et al. 2020).

Studies such as that of Armstrong-Mensah, et al. (2020), stressed the need for more reliable technology and educational resources that allow for an improvement in virtual teaching-learning conditions. This is also shared by other studies such as Borthwick and Hansen (2017) who, even before this health crisis, had announced the need for better technological conditions in education (Guasch, Alvarez and Espasa, 2010). Bojović, et al. (2020) stressed the importance of virtual platforms and digital support resources in these complex times. In addition, he also pointed out the urgency of teacher training in this regard. For instance, Chaka (2020) shared the similar idea, indicating that one of the main avenues of development in these times should be aimed at developing tools and technological supports that would facilitate the establishment of virtual teaching.

Research such as that of Bopegedera (2020) highlights the potential of educational strategies for this type of teaching transformation in fields such as chemistry. In educational fields as empirical and pragmatic as this one, authors revealed that with commitment, educational innovation and creativity, it is possible to achieve the students' engagement and guarantee an optimal learning environment (Shenoy, Mahendra and Vijay, 2020). Perets et al. (2020) were also committed to a teaching concept that facilitates the students' educational engagement. Their study focuses on encouraging greater participation and feedback in the educational process of their undergraduate chemistry students. Along the same lines, Silva, et al. (2020), in their study with dental students, also highlighted the value of support and teacher-student interaction as a key tool in distance education. With these findings in our review, studies such as that of González et al. (2020) reaffirmed this idea and added that, in difficult times of digitalization, platforms, resources, and virtual support are some of the keys to facing a new teaching scenario.

Another key point emerging from our findings was the evaluation of STEM and science education subject area practices in times of the pandemic. Due to the complexity of the situation, some articles in our review inquired into possible influencing factors and implications to be taken into account concerning this (Silva, et al., 2020; Barra, et al., 2020; Bojović, et al., 2020; Kamal, et al., 2020). García-Peñalvo et al. (2020) explained that the challenge undertaken in higher education in the digital scenario is unprecedented, and that, therefore, both students and faculty must build inclusive responses so that no one is left out.

Some of the pedagogical recommendations included in the findings of our review refer to the consideration of the overload of academic work that students may experience during online learning. Santuario (2020) agrees with this aspect, adding that, when faced with situations of this kind, understanding and flexibility are needed on the part of the teaching sector, taking into account the novelty of this teaching model for students in general. As for the dynamics and methodologies suggested for the area of science education, those that seek to create innovative content and evoke engagement take precedence. Also, feedback is considered fundamental in the learning process. Ordorika (2020) explains that in the absence of physical interaction at the educational level, proactivity and continuous virtual contact with students are one of the main ways to achieve good educational results.

Finally, based on the results of this literature review, we propose a series of initiatives and suggestions that could be useful for the development of inclusive practices in the field of science education in these times of pandemic.

On the one hand, the development of virtual dynamics (and even hybrid dynamics if the situation allows), in which the role of students as active subjects and protagonists of their teaching and learning process is promoted. To this end, two key aspects are essential. Firstly, the creation and development of secure and effective virtual tools that enable the development of content. Secondly, the use of these tools on a more continuous basis, regardless of whether the situation requires social distancing or not. Only in this way both students and teachers will be able to obtain the most out of this type of pedagogical practice.

However, the role of the teacher becomes essential in this type of distance education, as the degree of participation of their students depends on them. To this end, teachers must consider a series of key aspects such as creating flexible and formative assessment situations, developing a timetable in accordance with the virtual circumstance, presenting the content attractively and clearly, encouraging co-assessment processes, facilitating ways of reflecting on the individual practice of each student, etc, to contribute to increasing the students' motivation towards online participation. In this sense, at the level of educational policy, teacher training in issues related to this new virtuality in the teaching-learning process should be integrated as a basic pillar. This would be decisive for future crisees that require virtual or semi-virtual practices. We would like to point out that we consider that this training should include issues not only of training in the use of digital educational tools/resources but also of educational inclusion in an online scenario.

In line with this, due to the barrier of "non-presence" or "semi-presence", other resources and tools can promote active dynamics to create a participatory and inclusive climate in the classroom. In this sense, the use of virtual platforms has become a fundamental tool for the familiarisation, engagement, and mastery of this type of educational practice by the entire educational sector.

Finally, we consider that future lines of research should move towards analyzing the impact of different pedagogical approaches developed in the teaching of STEM areas during the health crisis by COVID-19. This would help us to build up a body of findings that would provide clues and lessons on teaching and learning issues. This type of research is encouraging and can serve as an example to other professionals to guide their actions in the classroom.

Findings

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