

Effects of the COVID-19 pandemic on architectural education: bibliometric and content analyses

COVID-19's
impact on
architectural
education

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Abstract

Purpose – The impact of the coronavirus disease 2019 (COVID-19) pandemic on architectural education (AE) was investigated, and a framework was proposed to reduce the impacts' negative consequences.

Design/methodology/approach – Systematic literature review, bibliometric and content analyses were combined to gain an in-depth understanding of the effects of the pandemic on AE and projections for its future. Relevant documents were extracted from the Web of Science (WoS) database. Bibliometric connections in the context of AE and COVID-19 pandemic were explored using text-mining and content analysis was performed.

Findings – The challenges, development tendencies and collaboration networks in AE during the pandemic were quantitatively and qualitatively analyzed. The most influential articles, journals, authors and countries/regions were highlighted using a bibliometric analysis. The analysis of keyword tendencies and clusters indicates that new concepts have emerged in AE research during the pandemic involving online, in-person and hybrid education. Using content analysis of 57 subtopics, 39 (18) were categorized as having negative (positive) effects. A comprehensive mitigation framework was designed to reduce the impact of the pandemic on AE.

Research limitations/implications – The study findings can enable practitioners to construct effective solutions to COVID-19- and other disaster-related problems regarding AE. The implications, obstacles and mitigation framework presented can help identify gaps in the literature and guide further research.

Originality/value – This paper presents the first bibliometric and content analysis of AE and COVID-19 pandemic-related studies published from January 2020 to June 2022 to highlight several research directions and academic development within the field.

Keywords COVID-19, Architectural education, Online education, Bibliometric analysis, Content analysis, Systematic review

Paper type Research paper

1. Introduction

Biological disasters, like natural disasters, have long-term effects on social behavior. This has sparked debate over the best course of action following such an event. The continuing coronavirus disease 2019 (COVID-19) outbreak has wreaked havoc across the globe, halting life in many areas (Varma and Jafri, 2021), forcing changes across all industries, professions and academic disciplines. As an unforeseen outbreak, it differed from previous global catastrophes (Harinarain, 2020), affecting economic systems, industries and all levels of education, with the risk of persistent losses worldwide (Franzese, 2020; Nicola *et al.*, 2020). Education has been one of the most affected environments, as different levels of education were suspended after face-to-face teaching became impossible to continue. The pandemic has forced universities to make crucial changes to maintain their community, faculty members and students safe (Megahed and Hassan, 2022). Universities with an online education infrastructure began remote teaching immediately; those without such an infrastructure quickly implemented an emergency plan (Akçay Kavakoğlu *et al.*, 2022). Various universities and institutions have discontinued education in favor of online education.



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Online education is a learning process conducted between lecturers and students (Martosenjoyo, 2021) generally using Internet facilities (Alkhalil *et al.*, 2021). Other definitions highlight the technology and changes in communication methods required to realize it (Sangrà *et al.*, 2012). Online education can be synchronous or asynchronous (Mukhopadhyay and Mukhopadhyay, 2020). In both types, the content of a course is delivered online and can be consumed by students regardless of their geographic locations. However, unlike asynchronous type, synchronous type includes live online sessions between students and teachers (Mukhopadhyay and Mukhopadhyay, 2020). Online education is the development of long-standing distance education (Martosenjoyo, 2021), which has a wider scope and also includes correspondence courses and satellite campuses (Sharma and Kitchens, 2004).

Online education allows students to access course materials anywhere at any time, without requiring proximity between students and teachers (Verawardina *et al.*, 2020). Despite its many advantages, this approach to education presents several challenges that differ from subject to subject (depending on their specific characteristics, requirements and educational philosophy).

Architectural education (AE) is not simply vocational education achieved through training. The educational process is usually not just about teaching how to solve problems, but also about determining what the problems are. In this respect, AE has its own specifications and is distinct from the practice of architecture and education in other disciplines (Gümüşburun Ayalp and Erman, 2019). Because of the open-edit nature of the design process and complexity of building systems, most architectural programs convene classes in design studios (Crowther, 2013; McCarthy and De Almeida, 2002; Shahda, 2019), which tend to be social environments. Compared with typical classrooms, studios allow students to interact intellectually and socially. Studios provide a multidimensional environment where students can spend their time, create their design work, interact, discuss and share with their peers (Ahmad *et al.*, 2020; Alnusairat *et al.*, 2021; Schön, 1987), and in the process, studios develop a sense of belonging to the architectural profession. Thus, AE offers hands-on learning in a studio setting (Ceylan *et al.*, 2021). Therefore, providing meaningful architectural design education and design studios (Ceylan *et al.*, 2021) during the pandemic has been a priority.

To prevent the spread of COVID-19, the architecture departments of universities have also shifted to online education like. Because of lockdowns due to COVID-19, the transition from traditional teaching in design studios to virtual courses, with very little resources and experience, has had a drastic impact on learning and teaching modes. Most instructors and students have had to address difficulties associated with new applications for online teaching in a very short time. Therefore, instructors and students have experienced several challenges (Ceylan *et al.*, 2021).

This situation has raised the interest of many researchers around the world, who have investigated it from various perspectives, such as exploring students' perception, satisfaction and evaluation of online learning (Peimani and Kamalipour, 2021b; Koh and Wong, 2021; Ceylan *et al.*, 2021; Asadpour, 2021; Bakir and Alsaadani, 2022; Al Maani *et al.*, 2021; Komarzyńska-Świeściak *et al.*, 2021; Alkhalil *et al.*, 2021; Alnusairat *et al.*, 2021; Elrawy and Abouelmagd, 2021); solving the challenges due to COVID-19 and proposing guidelines (Leon *et al.*, 2021; Güler, 2022; Dennis, 2021); developing virtual reality (VR) approaches for education (Wu *et al.*, 2021; Xi and Cong, 2022) and identifying facilitators and barriers for the adoption of online AE (Tandon *et al.*, 2021). Most previous studies involved individual cases or a single country (e.g. Egypt, Jordan, India, China, Turkey and Spain). Although these studies are impactful and significant, they mostly relied on online surveying, quantitative analyses, semi-structured interviews, case studies and experimental studies. However, to minimize the adverse effects and maximize the efficiency of online AE throughout the remainder of this pandemic and/or any future pandemic, it is critical to clearly understand how the transformation of education methods, from traditional in-person to online, has affected AE.

This paper aimed to fill the lacuna in quantitative and qualitative overviews of the impact of COVID-19 on AE research. This was conducted by applying bibliometric and content analyses to a dataset of related studies published between 2020 and June 2022. Bibliometric techniques allow quantitative assessment of the development of research in a specific area (van Raan, 2005). The consequences of COVID-19 on AE were evaluated to achieve four goals: use bibliometric analysis (1) to reveal the development tendencies in pandemic-related AE research, (2) to suggest new areas of research in AE by mapping existing literature, (3) use content analysis to determine the challenges and positive effects of COVID-19 on AE not limited to a specific country by generalizing the research from all countries and (4) to identify mitigation strategies to minimize the adverse effects of the pandemic. The study will aid academics in identifying and addressing gaps in the existing literature, while also seeking new manners in which the COVID-19 pandemic and any forthcoming global crisis could influence AE.

2. Research background and gaps in literature

For many years, higher education institutions have been moving toward digital transformation in education. Digital spaces that allow students to share work and interact asynchronously have been created to remotely provide design studio experience (Lotz *et al.*, 2015). Virtual studios (Lahti and Seitamaa-Hakkarainen, 2014; Salman *et al.*, 2017; Jones *et al.*, 2021) and blended learning approaches (Mohammed, 2017; Rodriguez *et al.*, 2018) have achieved some success by utilizing formal online spaces to encourage collaborations. Remarkably, these attempts were made under normal conditions when there was no obligation to transition to online architecture education. However, all AE stakeholders are now faced with an unforeseen situation *vis-à-vis* the pandemic.

The COVID-19 pandemic has hampered AE in an unpredictable manner. Since the 2019–2020 academic year spring term, almost every design studio and theoretical course has become online. The shifted mode of education has been called “emergency remote teaching” or “transitional emergency model” (Hodges *et al.*, 2020; Salama and Crosbie, 2020). Although some architecture schools (e.g. Tulane University School of Architecture, Kent State University College of Architecture and Environmental Design) adapted quickly and easily to the transition to online education (Archinect, 2020a), others encountered several obstacles (e.g. University of Bath) (Grover and Wright, 2020).

Several professional organizations have drawn attention to the importance of this issue. Salama and Crosbie (2020) published a pioneering and credible report according to which AE is passing through a “transitional emergency model.” Owing to the several challenges, mitigation strategies are required to adapt to this situation. Another significant case report was published by Grover and Wright (2020), who conducted a survey through a questionnaire (National Design Studio Survey) at the Department of Architecture and Civil Engineering, University of Bath, gathering the perceptions of instructors and students on the impact of COVID-19 on design studios. According to the survey, learning satisfaction decreased by 58% with online education, peer learning was the most adversely affected and design studio culture was harmed by students feeling isolated. Along with this report, Gloster (2020), a Royal Institute of British Architects (RIBA) advisor, provided suggestions to architecture students regarding improving focus during online classes.

Professional organizations evaluated the state of AE in the current situation of the pandemic and also made projections for its post-pandemic future. Globally, educational institutions have showed an interest in assessing the impact of adaptation of online learning on teaching and academic activities in AE to forecast its long-term effect on academia. There is strong support for sustaining online teaching of architectural courses because of its advantages, such as providing a multi-sensory experience, allowing combinations of

individualized synchronous and asynchronous learning (Ockert, 2020). Despite the support for continuation of digital education in the future, there is definitive agreement on the critical importance of physical studio space for education in architecture. A consensus among academic leaders predicts the post-pandemic future of AE to be a hybrid of in-class and online in terms of content delivery, assessments and other academic aspects (Architect, 2020a, b, c). Blended learning, with the inclusion of online education, presents multiple advantages that can enhance undergraduate architecture learning experience (Koponen and Kivimäki, 2015; Ioannou, 2018; Carpo, 2020).

Along with an educational methodology shift in AE, this subject has attracted the attention of many researchers around the world, who have investigated it from different perspectives, as previously mentioned.

Various methodologies and quantitative research methods have been employed in related studies, such as conducting an online survey of architecture students and analyzing data using descriptive statistics (Koh and Wong, 2021; Varma and Jafri, 2021; Peimani and Kamalipour, 2022; Güler, 2022), exploratory factor analyses (Asadpour, 2021), structural equation modeling (Tandon *et al.*, 2021) and analytic hierarchy process (Tang *et al.*, 2021). Other studies adopted qualitative analyses or mixed approaches, including semi-structured interviews and online surveys (Megahed and Hassan, 2022), experimental studies (Wu *et al.*, 2021), surveys, case studies and structural equation modeling (Akçay Kavakoğlu *et al.*, 2022) and focus group interviews, questionnaire surveys and statistical analyses (Ibrahim *et al.*, 2021). However, a systematic literature review (SLR) or content and bibliometric analysis has not been conducted to map AE and COVID-19 pandemic online education.

Although several attempts have been made to evaluate the shift in AE studies due to the pandemic, they have failed to provide an in-depth understanding of the effect of COVID-19 effects on AE. Therefore, a rigorous bibliometric and content analysis of existing was conducted to examine its intellectual core and deficiencies and omissions. To mitigate the adverse effects and increase the positive impacts of transformed AE, a greater understanding is required. We use a mixed approach of SLR and content and bibliometric analyses to highlight the effect of the COVID-19 pandemic on AE.

3. Research methodology

Data were collected using SLR and processed using bibliometric and content analyses. Methodological approach of this study is presented in Figure 1.

3.1 Data collection

Data were collected through an SLR within the Web of Science (WoS) database, and bibliographic records were downloaded for analysis. WoS contains nearly all major research articles and includes built-in analytic capabilities for producing representative numbers (Yu *et al.*, 2020), with better citation-matching algorithms than Scopus (Valderrama-Zurián *et al.*, 2015), being a useful data-source.

SLR is a research method used to locate and critically evaluate relevant research, as well as to gather and analyze data from that study (Liberati *et al.*, 2009). An SLR on the impact of COVID-19 on AE was conducted (Figure 2).

The retrieval schemas used to search the WoS database are as follows: (ALL FIELDS) “online education” AND “architecture education” AND “COVID-19”. The timeframes considered were January 2020 and June 2022. The search yielded 120 publications, of which one was a duplicate and was excluded. Some of these records included irrelevant disciplines such as theater or robotics. A manual screening was performed to filter out irrelevant records. The 119 articles extracted were carefully refined based on specific

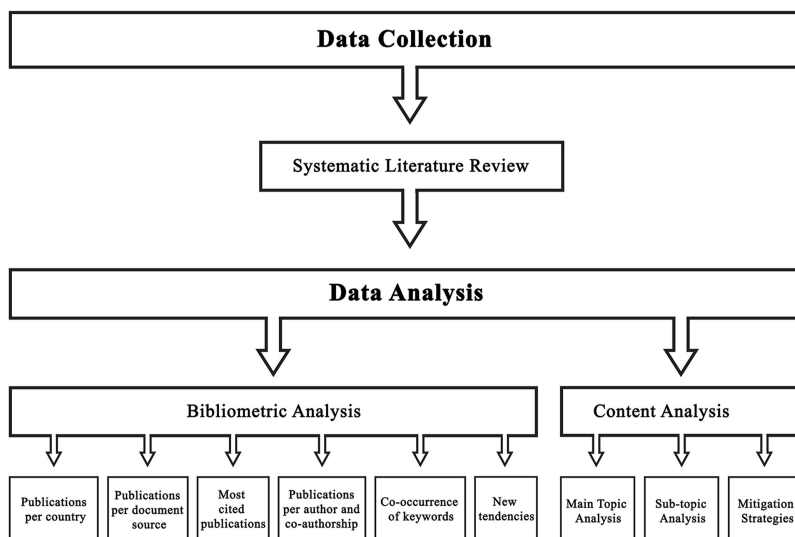


Figure 1.
Overall research
methodology

parameters: field (AE), publication language (English), and publication type. Filtering excluded 45 records. In the next step, well-defined inclusion and exclusion criteria were applied. In this scope, all the obtained documents were reviewed as full text and 44 documents were removed (Kitchenham and Charters, 2007). The authors independently read the abstracts, introductions and conclusions of all the papers to confirm that they were relevant. To validate the results, each author individually applied the inclusion and exclusion parameters and obtained the same results. A total of 30 articles were chosen for assessment.

The remaining 30 articles were downloaded as comma-separated values (CSV) files and used for the bibliometric analysis. The CSV file included the data as follows: title of article, year of publication, author, affiliation of authors, abstract, article keywords, journal volume and page numbers, citation information, reference list and the digital object identifier of extracted articles. For bibliometric analysis (Najmi *et al.*, 2017), direct citation networks and co-occurrence networks were generated from this data.

3.2 Data analysis

To comprehensively identify and analyze the contents of the selected publications, the analyses were further separated into two subcategories as follows: bibliometric analysis and content analysis.

3.2.1 Bibliometric analysis. Bibliometric analysis is a scientific strategy for quantitatively analyzing research publications on a certain topic using mathematical methods (Yu *et al.*, 2020). This method examines the unique characteristics of publications and documents to uncover links between different components of scientific communication (Esen *et al.*, 2020). To explore the effects of the COVID-19 pandemic on AE, we used the VOSviewer text-mining tool to analyze bibliometric connections based on certain results. Bibliometric analysis-based on six criteria was performed on the downloaded dataset: (1) publications per country, (2) publications per document source, (3) the most cited publications, (4) publications per author and their co-authorship, (5) co-occurrence of keywords and (6) new tendencies.

3.2.2 Content analysis. Although bibliometric analysis is a useful technique for evaluating academic output, it does not provide precise information on the topic of interest

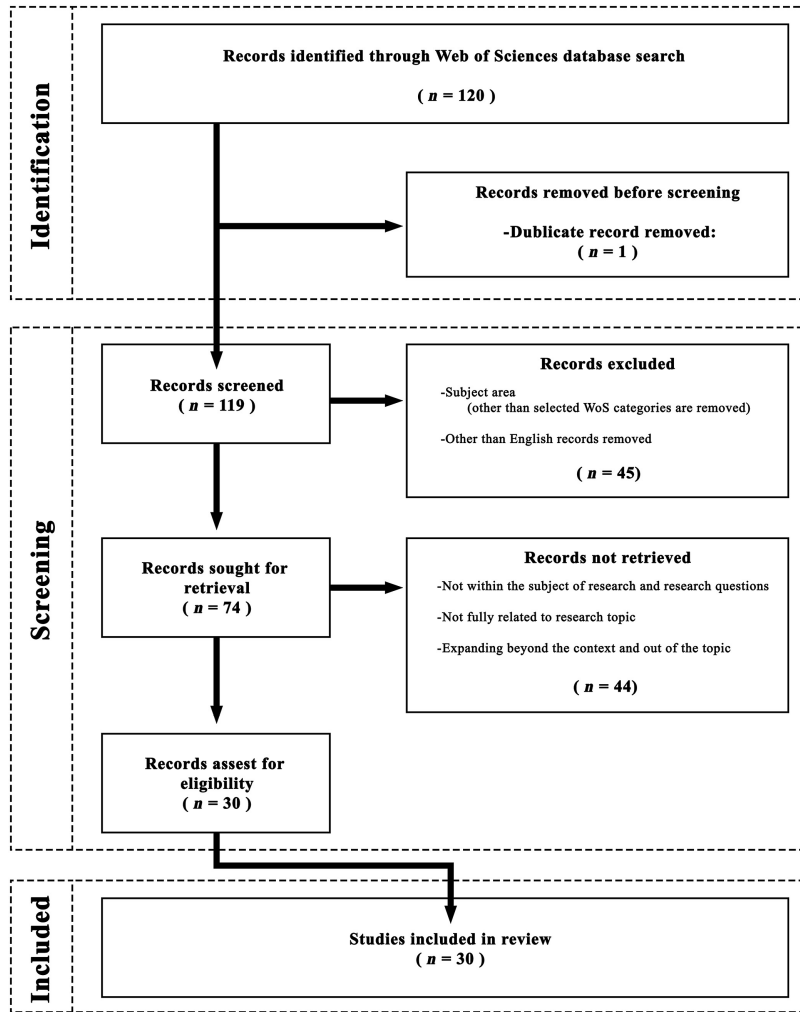


Figure 2. Flow diagram for SLR methodology

(Esen *et al.*, 2020; Liang and Shi, 2021). Therefore, content analysis was employed to gain deeper knowledge of the themes in the papers included in the dataset. Content analysis is a qualitative research approach for interpreting meanings from textual data. Three content analysis approaches are commonly used: conventional, directed and summative (Hsieh and Shannon, 2005). When available theory or literature on the issue is limited, conventional content analysis should be applied (Ayat *et al.*, 2021). Considering the time lag between the onset of the COVID-19 pandemic and its effects on AE, the body of research related to this pandemic and AE is limited. Therefore, conventional content analysis was employed, and the coding categories were extracted directly from the text data.

4. Results

The results of this study are based on bibliometric analyses and content analyses.

4.1 Bibliometric analysis

4.1.1 Publications by country. Table 1 shows the 19 countries where the COVID-19 pandemic and AE-related studies were conducted as well as the distribution of research in this field by country.

As shown in Table 1, the countries that contributed the most to the literature were Egypt, Jordan and India (four articles per country), followed by China and Wales with three articles each.

4.1.2 Publications per document source. The number of papers in the domain of the dataset, published in each journal, was analyzed, providing information about the most notable journals that publish AE education and pandemic-related studies. In total, 30 extracted publications were published in 20 journals. Table 2 provides the sources with at least one published document on AE and pandemics from the dataset.

As seen in Table 2, “Open House International (OHI),” “Archnet-IJAR: International Journal of Architectural Research” and “Education Sciences” are the top three of the list. The OHI, which had the most publications (five), is one of the leading built-environment journals that embrace interdisciplinary research in built-environment studies, establishing effective links between theory and design and education and practice in these fields. These research areas make the OHI authoritative among the researchers. Based on the highest total link strength, “Archnet-IJAR: International Journal of Architectural Research” and “Open House International” are the top 2 journals.

4.1.3 Most cited publications and research methods. The most cited documents were identified to determine the most relevant publication on the effects of the pandemic on AE, which were published within the timeframe considered. The publications that have been cited at least once were analyzed as shown in Table 3. The number of citations was extracted from the WoS dataset. Of the 30 selected publications, 22 were cited at least once.

From Table 3, the most cited publications are about architecture students’ satisfaction with online studios and the challenges and problems of online AE. Some areas are noteworthy, such as blended learning and sustainable teaching. With the COVID-19

Rank	Country	Number of publications	Number of citations	Total link strength
1	Egypt	4	6	0
2	Jordan	4	30	0
3	India	4	17	0
4	China	3	3	1
5	Wales	3	23	0
6	Spain	2	8	1
7	Turkey	2	14	1
8	Belgium	1	1	1
9	Nigeria	1	0	1
10	Poland	1	1	1
11	South Africa	1	0	1
12	Taiwan	1	2	1
13	England	1	0	0
14	Malaysia	1	0	0
15	The Netherlands	1	2	0
16	Serbia	1	11	0
17	The USA	1	0	0
18	Indonesia	1	2	0
19	Iran	1	0	0

Table 1.
 Number of
 publications
 by country

Table 2.
Number of
publications per source

Rank	Journal	Documents (January 2020–June 2022)	Citations	Total link strength
1	<i>Open House International</i>	5	11	9
2	<i>Archnet-IJAR: International Journal of Architectural Research</i>	4	41	16
3	<i>Education Sciences</i>	3	23	0
4	<i>Sustainability</i>	2	16	0
5	<i>Ain Shams Engineering Journal</i>	1	7	3
6	<i>e-learning and Digital Media</i>	1	0	3
7	<i>European Journal of Sustainable Development</i>	1	1	3
8	<i>International Journal of Mobile and Blended Learning</i>	1	0	2
9	<i>Applied Sciences-basel</i>	1	0	0
10	<i>Buildings</i>	1	1	0
11	<i>Cogent Education</i>	1	0	0
12	<i>Engineering Construction and Architectural Management</i>	1	3	0
13	<i>Ethics and Information Technology</i>	1	2	0
14	<i>Journal of Architectural Education</i>	1	0	0
15	<i>Journal of Engineering Science and Technology</i>	1	0	0
16	<i>Journal of Human Behavior in the Social Environment</i>	1	4	0
17	<i>Journal of Intelligent and Fuzzy Systems</i>	1	1	0
18	<i>Land</i>	1	2	0
19	<i>International Journal of Early Childhood Special Education</i>	1	2	0
20	<i>International Journal of Technology and Design Education</i>	1	0	0

pandemic, online education emerged rapidly and brought with it both challenges and benefits. Its emergence has seen a proliferation of new AE teaching methods.

The research methodological frameworks of the selected studies are listed in [Table 3](#). These can be divided into three major categories: qualitative, quantitative and mixed methodologies, with nine, eight and five articles using these approaches, respectively, as presented in [Table 3](#).

4.1.4 Publication per author and co-authorship network. A co-authorship analysis was generated using VOSviewer to identify the networks of authors that had undertaken collaborative research on the influence of pandemics on AE. The 30 documents assessed have 81 authors from 41 institutions, including the lead and co-authors. With the VOSviewer analytical function set to a minimum of 2 citations per author, 58 authors met the threshold as shown in [Table 4](#). [Table 4](#) presents a list of authors with the most documents and citations in the research domain, who have made significant contributions to research on COVID-19 and AE.

An analysis of the most productive authors revealed that Kamalipour, H. (3 documents, 23 citations), Peimani, N. (3 documents, 23 citations), Al Maani, D. (2 documents, 19 citations), Al-Jokhdar, A. (2 documents, 19 citations) and Alnusairat, S. (2 documents, 19 citations) were the most productive authors in this domain.

4.1.5 Co-occurrence keyword analysis. Keywords are significant words that serve as a point of reference and aid the description of content and understanding of concepts in research articles ([Su and Lee, 2010](#); [Olawumi and Chan, 2018](#)). Numerous topics and themes have evolved in research on COVID-19 and AE within the last two years. A visualization map of

Rank	Source	Source title	Number of citations	Research area	Research method
1	Peimani and Kamalipour (2021a)	Online Education and the COVID-19 Outbreak: A Case Study of Online Teaching during Lockdown	19	Teaching design methods during pandemic	Qualitative method <i>Case study</i>
2	Alnusairat et al. (2021)	Architecture students' satisfaction with and perceptions of online design studios during COVID-19 lockdown: the case of Jordan universities	16	Students' satisfaction with online design studios	Quantitative method <i>Survey results with descriptive statistics</i>
3	Milovanović et al. (2020)	Transferring COVID-19 Challenges into Learning Potentials: Online Workshops in Architectural Education	11	Developing new approaches in teaching and improving curricula	Qualitative method <i>Case study</i>
4	Ceylan et al. (2021)	An evaluation of online architectural design studios during COVID-19 outbreak	11	Investigating the architecture students' evaluation about the online design studio	Quantitative method <i>Survey results with descriptive statistics</i>
5	Varma and Jafri (2021)	COVID-19 responsive teaching of undergraduate architecture programs in India: learnings for post-pandemic education	10	Consequences of the pandemic on AE	Quantitative method <i>Survey results with descriptive statistics</i>
6	Ibrahim et al. (2021)	Evaluation of the online teaching of architectural design and basic design courses case study: College of Architecture at JUST, Jordan	7	Evaluation of the online education of architectural design	Mixed method <i>Focus group interviews (qualitative methods) descriptive statistics (quantitative methods)</i>
7	Leon et al. (2021)	BIM Application for Sustainable Teaching Environment and Solutions in the Context of COVID-19	5	Solve challenges during the pandemic in AE by means of BIM and communication technologies	Qualitative method <i>Case study</i>
8	Megahed and Hassan (2022)	A blended learning strategy: reimagining the post-Covid-19 architectural education	4	Proposing a blended learning strategy	Qualitative methods <i>Semi-structured interviews Literature review</i>

(continued)

Table 3.
Number of most
cited documents

Rank	Source	Source title	Number of citations	Research area	Research method
9	Peimani and Kamalipour (2021b)	Online Education in the Post COVID-19 Era: Students' Perception and Learning Experience	4	Architecture students' perception of blended online learning	Quantitative method <i>Survey results with descriptive statistics</i>
10	Alkhalil et al. (2021)	COVID-19 pandemic and the E-learning in higher institutions of education: faculty of engineering and technology at Al-Zaytoonah University of Jordan as a case study	4	Students' satisfactions with the online methods	Quantitative method <i>Survey results with descriptive statistics</i>
11	Akçay Kavakoglu et al. (2022)	Architectural design communication (ADC) in online education during COVID-19 pandemic: a comparison of Turkish and Spanish universities	3	Concept of architectural design communication for internal dynamics of AE	Mixed method <i>Case study (qualitative methods) survey and structural equation modeling (quantitative methods)</i>
12	Tandon et al. (2021)	E-learning adoption by undergraduate architecture students: facilitators and inhibitors	3	Challenges and facilitators for the adoption in Ae online education	Quantitative method <i>Survey results with structural equation modeling</i>
13	Al Maani et al. (2021)	Transforming learning for architecture: online design studio as the new norm for crises adaptation under COVID-19	3	Architecture students' perception and experiences related to quality of online design courses	Quantitative method <i>Survey results with descriptive statistics</i>
14	Andiyan et al. (2021)	Disruption of IoT in Adapting Online Learning during the Covid-19 Pandemic	2	Mapping the students' digital adaption to online lessons for studio courses	Mixed method <i>Case study (qualitative methods) survey and descriptive statistics (quantitative methods)</i>
15	Wu et al. (2021)	A Spherical Video-Based Immersive Virtual Reality Learning System to Support Landscape Architecture Students' Learning Performance during the COVID-19 Era	2	Developing video-based virtual reality approach for design courses	Qualitative method <i>Experiential study</i>

Table 3.

(continued)

Rank	Source	Source title	Number of citations	Research area	Research method
16	Dennis (2021)	Digital well-being under pandemic conditions: catalysing a theory of online flourishing	2	Strategies for digital well-being for AE during pandemic	Qualitative method <i>Exploratory research approach</i>
17	Khan and Thilagam (2021)	The confluence approach – a theoretical proposition for effective structuring of architecture studio pedagogy in e-learning mode	2	Structuring of architecture studio pedagogy for online education	Qualitative method <i>Exploratory research approach</i>
18	Khan and Thilagam (2022)	The virtual design studio and the key integrals	2	Critical drivers for virtual design courses	Qualitative method <i>Systematic approach</i>
19	Elrawy and Abouelmagd (2021)	Architectural and Urban Education in Egypt in the Post Covid-19 Pandemic	1	Changes in AE during pandemic	Mixed method <i>Literature review, interviews (qualitative methods) descriptive statistics (quantitative methods)</i>
20	Bakir and Alsaadani (2022)	A mixed methods study of architectural education during the initial COVID-19 lockdown: student experiences in design studio and technology courses	1	Architecture students' experiences of online education	Quantitative method <i>Survey results with descriptive statistics</i>
21	Tang <i>et al.</i> (2021)	Quality evaluation of online courses during COVID-19 pandemic based on integrated FCE-AHP method	1	Quality of online courses in AE	Mixed method <i>Analytical hierarchy process</i>
22	Komarzyńska-Świeściak <i>et al.</i> (2021)	Transition from Physical Design Studio to Emergency Virtual Design Studio. Available Teaching and Learning Methods and Tools-A Case Study	1	Students' perception transition from physical to emergency design studio	Qualitative method <i>Case study</i>

Table 3.

keywords in the selected papers, showing co-occurrences and a network of research topics on COVID-19 and AE, was created using data from the WoS database using the VOSviewer. The degree of co-occurrence depends on the similarity of keywords and how close they are to each other on the map (Van Eck and Waltman, 2020; Liang *et al.*, 2020).

No	Author	Number of documents	Institution	Country	Number of citations	Total link strength
1	Hesam Kamalipour	3	Cardiff University	United Kingdom	23	3
2	Nastaran Peimani	3	Cardiff University	United Kingdom	23	3
3	Duaa Al Maani	2	Applied Science Private University	Jordan	19	4
4	Amer Al-jokhdar	2	University of Petra	Jordan	19	4
5	Saba Alnusairat	2	Al-Ahliyya Amman University	Jordan	19	4
6	Asif R. Khan	2	Kalasalingam Academy of Research and Education	India	4	2
7	N. Lakshmi Thilagam	2	Kalasalingam Academy of Research and Education	India	4	2
8	Naglaa Megahed	2	Port Said University	Egypt	4	1
9	Jovana Bugarski	1	University of Belgrade	Serbia	11	8
10	Aleksandra Dordevic	1	University of Belgrade	Serbia	11	8
11	Andrej Josifovski	1	University of Belgrade	Serbia	11	8
12	Milos Kostic	1	University of Belgrade	Serbia	11	8
13	Aleksandra Milovanović	1	University of Belgrade	Serbia	11	8
14	Mladen Pesic	1	University of Belgrade	Serbia	11	8
15	Neda Sokolovic	1	University of Belgrade	Serbia	11	8
16	Dejan Todorovic	1	University of Belgrade	Serbia	11	8
17	Ana Zoric	1	University of Belgrade	Serbia	11	8
18	Eman A. Abdelhafez	1	Al-Zaytoonah University of Jordan	Jordan	4	5
19	Shahnaz M. Alkhalil	1	Al-Zaytoonah University of Jordan	Jordan	4	5
20	Andiyan Andiyan	1	Universitas Faletahan	Indonesia	2	5
21	Esra'a A. Bashayreh	1	Al-Zaytoonah University of Jordan	Jordan	4	5
22	Loai M. Dabbour	1	Al-Zaytoonah University of Jordan	Jordan	4	5
23	Yulius Hari	1	Universitas Widya Kartika	Indonesia	2	5
24	Ahmad A. Manasrah	1	Al-Zaytoonah University of Jordan	Jordan	4	5
25	Esraa G. Rababa	1	Al-Zaytoonah University of Jordan	Jordan	4	5

Table 4.
Number of documents
per author

(continued)

No	Author	Number of documents	Institution	Country	Number of citations	Total link strength
26	Dadan Rusmana	1	UIN Sunan Gunung Djati	Indonesia	2	5
27	Michael Sitorus	1	BRI Institute	Indonesia	2	5
28	Miftahus Surur	1	STKIP PGRI Situbondo	Indonesia	2	5
29	Zulvia Trinova	1	UIN Imam Bonjol Padang	Indonesia	2	5
30	Salih Ceylan	1	Bahcesehir University	Turkey	11	4
31	Pinar Şahin	1	Bahcesehir University	Turkey	11	4
32	Serengul Secmen	1	Bahcesehir University	Turkey	11	4
33	Melek E. Somer	1	Bahcesehir University	Turkey	11	4
34	Kemal H. Suher	1	Bahcesehir University	Turkey	11	4
35	A. Akcay Kavakoglu	1	Istanbul Technical University	Turkey	3	3
36	Hikmat H. Ali	1	Jordan University	Jordan	7	3
37	Ahmed S. Attia	1	Jordan University	Jordan	7	3
38	Kanika Bansal	1	Chitkara University	India	3	3
39	Asma'm Bataineh	1	Jordan University	Jordan	7	3
40	Harveen Bhandari	1	Chitkara University	India	3	3
41	Omer Bilen	1	Bursa Technical University	Turkey	3	10
42	Jiang-Jie Chen	1	Tatung University	Taiwan	2	3
43	Debora Domingo-Callabuig	1	Universitat Politecnica de Valencia	Spain	3	10
44	Derya Gulec Ozer	1	Istanbul Technical University	Turkey	3	10
45	Yen Hsu	1	Tatung University	Taiwan	2	3
46	Inigo Leon	1	University of the Basque Country	Spain	5	3
47	Amit Mittal	1	Chitkara University	India	3	3
48	Fernando Mora	1	University of the Basque Country	Spain	5	3
49	Juan Pedro Otaduy	1	University of the Basque Country	Spain	5	3
50	Maialen Sagarna	1	University of the Basque Country	Spain	5	3
51	Urvashi Tandon	1	Chitkara University	India	3	3
52	Wei-Long Wu	1	Tatung University	Taiwan	2	3
53	Qi-Fan Yang	1	Fujian Normal University	China	2	3
54	Anwar F. Ibrahim	1	Jordan University	Jordan	7	3
55	Asmaa Hassan	1	Port Said University	Egypt	4	1
56	Mohammed S. Jafri	1	Amity University	India	10	1
57	Anurag Varma	1	Amity University	India	10	1
58	Matthew J. Dennis	1	Technische Universiteit Delft	Netherlands	2	0

Table 4.

4.1.5.1 Keyword co-occurrence clusters. Keyword co-occurrence analysis determines the clusters of research topics on the COVID-19 and AE and highlights the most relevant topics. The keyword clusters indicate the categories and themes and directions of research.

Using VOSviewer software, a co-occurrence network from 120 keywords was generated. The inclusion criterion for keywords was a minimum of 2 co-occurrences, which was satisfied by 21 keywords. Using clustering, four keyword clusters were observed. A network visualization map depicting the four keyword clusters is shown in Figure 3. It has 94 links, with total link strength of 147. As shown in Figure 3, the size of the nodes represents the occurrence frequency of the keyword. A larger node indicates a more frequently occurring keyword. In addition, the thickness of lines indicates the co-occurrence relationship between nodes. The thicker the lines, the greater the relationship (Van Eck and Waltman, 2020). Based on the co-occurrence of keyword analysis, keywords were classified into topics according to similar research areas as shown in Figure 3. Using VOSviewer, keywords from similar or interrelated research areas are displayed closer to each other. In addition, the interrelations between these keywords are linked by lines, which allows for easier interpretation.

Cluster 1 (red) involves keywords related to *students' experience with online AE during pandemic*, such as “pandemic,” “higher education” and “student experience.” Cluster 2 (green) involves keywords related to *transition to and adoption of online AE*, such as “online learning,” “online education,” “design studio,” “architectural education” and “adaptation.” Cluster 3 (blue) involves keywords related to *blended learning*, such as “blended online learning,” “education” and “technology.” Cluster 4 (yellow) focuses on *AE pedagogy and curriculum development* with keywords such as “architecture studio pedagogy” and “virtual design studio.”

Table 5 lists the most active keywords in the 30 analyzed documents from the co-occurrence keyword analysis. For ranking, 2 co-occurrence keywords were accepted as the threshold. “COVID-19” was the most frequently occurring keyword with 15 occurrences, followed by “online learning” (8 occurrences) and “online education” (6 occurrences).

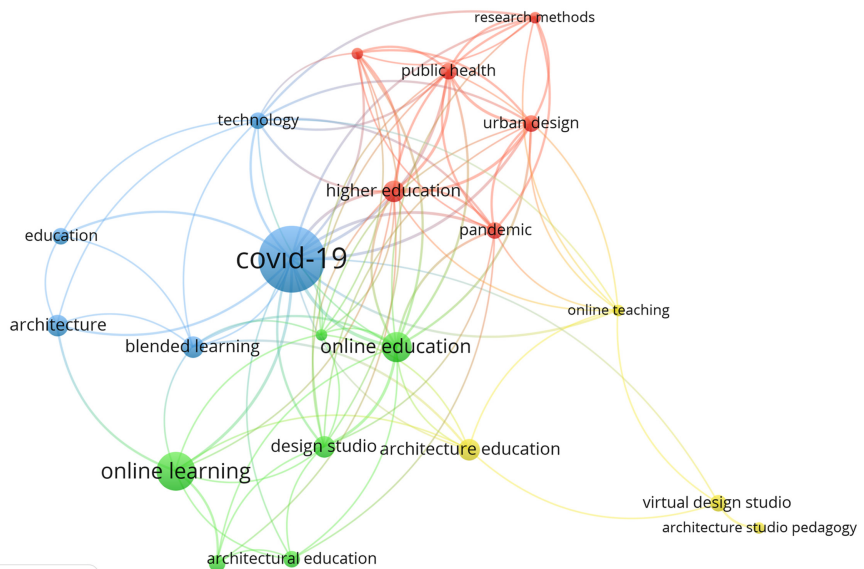
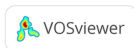


Figure 3. Keyword co-occurrence analysis network visualization



Rank	Keyword	Occurrences	Total link strength
1	COVID-19	15	84
2	Online Learning	8	31
3	Online Education	6	43
4	Higher Education	4	36
5	Design Studio	4	27
6	Architecture	4	18
7	Blended Learning	4	17
8	Architecture Education	4	16
9	Public Health	3	33
10	Urban Design	3	33
11	Technology	3	25
12	Pandemic	3	24
13	Virtual Design Studio	3	18
14	Architectural Education	3	16
15	Covid-19 Pandemic	3	14
16	Education	3	13
17	Student Experience	2	25
18	Research Methods	2	20
19	Distance Education	2	17
20	Architecture Studio Pedagogy	2	13
21	Online Teaching	2	13

Table 5.
Keywords occurrences
and total link strength

4.1.5.2 Annual tendencies of research topic analysis. An overlay visualization network obtained using VOSviewer representing the evolution of research topics initiated by the pandemic during 2020–2022, represented by co-occurring keywords, is shown in Figure 4.

The network and links show an increase in publications during the first year of the pandemic on topics such as COVID-19, online learning and online teaching in AE. After the second half of 2021, more specific issues were addressed, such as design studios, virtual design studios, technology and student experience. From 2022 onward, keywords such as

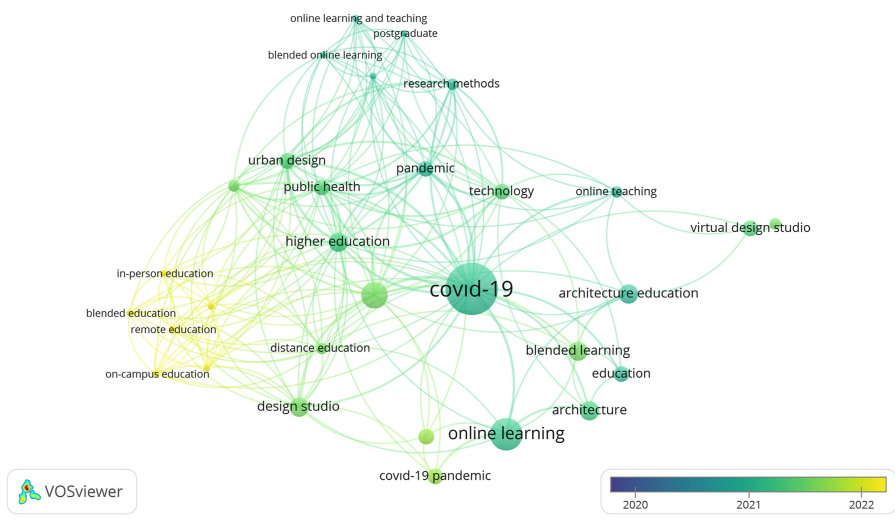


Figure 4.
Overlay visualization
of research topics – a
network map of
research themes during
January 2020 to June
2022, based on
keywords

blended, face-to-face, virtual, in-person, on-campus and remote education were found to co-occur. During the last period, interest in hybrid AE increased.

Thus, research on the COVID-19 pandemic and AE has evolved from understanding and adopting online AE to new educational approaches for the future (Figure 4).

4.2 Content analysis

For a more detailed analysis, content analysis was separately performed on three categories: main topic, subtopic and mitigation strategies. Among these, the main topic analysis was conducted to grasp the key topics in the evaluated publications, whereas subtopic analysis yielded information about the many effects of pandemics on AE. Finally, the mitigation strategies and techniques discussed by various researchers were analyzed. The results of each type of analysis are described below.

4.2.1 Main topic analysis. The COVID-19 pandemic has significantly affected AE (Ceylan *et al.*, 2021; Elrawy and Abouelmagd, 2021; Ibrahim *et al.*, 2021), and the effects of the current pandemic on AE have been examined (Varma and Jafri, 2021; Asadpour, 2021; Bakir and Alsaadani, 2022). The major themes and issues of the research were determined based on an initial review of the sample (Table 6).

Researchers were most interested in the influence of the COVID-19 pandemic on AE, challenges, the quality of online AE, potential curriculum revisions and adaptation challenges. Projections for post-pandemic and future AE are important topics. Blended learning and digital integration into education using instruments such as building information modeling (BIM) and VR were the next most popular topics. Researchers have used a variety of techniques to determine how the pandemic has impacted AE and how students and instructors are adjusting to the changes. These included a pedagogical perspective to discuss how technology-based models interact and integrate with AE (Megahed and Hassan, 2022), as well as to implement these models these impacts from the perspectives of educators of architecture programs in the aftermath of the pandemic (Varma and Jafri, 2021). The pandemic has also had a progressive effect on educational evolution,

Rank	Main topic	Number of sources	Scope of papers
1	Exploring students' perception and evaluation of online learning	8	Malaysia, Turkey, Iran, Egypt, Poland, Jordan (2) and Wales
2	Solving the challenges and proposing a guideline	3	The USA, Spain and the Netherlands
3	Evaluations of online learning and exploring the students' perceptions	3	India, Nigeria and Jordan
4	Proposing of the blended learning approaches for architectural education	3	Egypt (2) and Wales
5	Pedagogical contribution approaches for online design education	2	India (2)
6	Assessing architecture students' satisfaction with perceptions of online design courses during pandemic	2	Egypt and Jordan
7	Developing new virtual reality approaches	2	China (2)
8	Architectural Design Communication	2	Turkey–Spain and Indonesia
9	Exploring challenges and opportunities of online education	2	Serbia and Wales
10	Evaluation of the online courses' quality	1	China
11	Identifying facilitators and inhibitors of adoption	1	India
12	Digital Domesticity and Magical Realism	1	England

Table 6.
Classification of
main subjects

creating a new potential in AE, which has emerged as a subject of study. Komarzyńska-Swieściak *et al.* (2021) conducted a case study on the transition from physical to virtual studios using current learning and teaching methods and tools. Milovanović *et al.* (2020) illustrated how current pandemic challenges can be transformed into learning potential by a case study. Several other studies have described this viewpoint in architectural curricula (Ibrahim *et al.*, 2021; Dennis, 2021). Leon *et al.* (2021) explored improvement options in specific areas, such as BIM, whereas other scholars investigated this within the concept of case studies (Peimani and Kamalipour, 2021a; Xi and Cong, 2022). Additionally, Akçay Kavakoğlu *et al.* (2022) concentrated on the concept of architectural design communication for updating design studio dynamics during the COVID-19 pandemic.

In addition to academic documents, several professional organizations have published credible reports on this issue. Academic leaders discussed institutional responses to the pandemic (Archinect, 2020a), long-term impacts of the pandemic on architecture (Archinect, 2020b) and the impact of COVID-19 on year-end activities (Archinect, 2020c). Salama and Crosbie (2020) focused on reshaping the future of AE in the post-pandemic world. Gloster (2020) investigated manners to maintain the focus of architecture students during the COVID-19 crisis.

4.2.2 Subtopic analysis. A thorough examination of subtopics was conducted to understand the precise variables explored in the documents, such as to obtain specific information about the nature of the influence of COVID-19 on AE from each document. These characteristics were categorized into negative (Table 7) and positive (Table 8) impacts. To integrate the results of bibliometric analysis with content analysis, each group was divided into one of four sub-categories identified in the keyword co-occurrence analysis (Section 4.5.1): (1) students' experience with online education during the pandemic, (2) transition and adoption of online AE, (3) blended learning and (4) AE pedagogy and curriculum development.

4.2.2.1 Negative impacts. The ongoing pandemic has amplified inefficiencies and flaws in AE. Table 7 lists 39 negative factors under the four subcategories.

Students' negative experience with online education during pandemic. The COVID-19 pandemic has had negative consequences for students on a large scale. The most prominent challenges include technical issues (Megahed and Hassan, 2022; Peimani and Kamalipour, 2021a; Ibrahim *et al.*, 2021); technological complexity (Andiyan *et al.*, 2021); lack of fast and stable Internet connection (Alnusairat *et al.*, 2021; Peimani and Kamalipour, 2021a, b; Ibrahim *et al.*, 2021; Asadpour, 2021; Andiyan *et al.*, 2021; Milovanović *et al.*, 2020; Alkhalil *et al.*, 2021; Varma and Jafri, 2021; Elrawy and Abouelmagd, 2021; Gambo and Musonda, 2022; Bakir and Alsaadani, 2022; Güler, 2022; Khan and Thilagam, 2022; The Second Studio Podcast, 2020); difficulties in understanding teachers' instructions online (Alnusairat *et al.*, 2021; Asadpour, 2021; Tandon *et al.*, 2021; Elrawy and Abouelmagd, 2021; Al Maani *et al.*, 2021); increased sense of isolation and disconnection from peers and colleagues (Megahed and Hassan, 2022; Tang *et al.*, 2021; Koh and Wong, 2021; Salama and Crosbie, 2020; Bakir and Alsaadani, 2022; Grover and Wright, 2020); psychological problems/negative feelings that could lead to alienation, uncertainty, confusion and identity loss (Megahed and Hassan, 2022; Ceylan *et al.*, 2021; Alnusairat *et al.*, 2021; Ibrahim *et al.*, 2021; Gambo and Musonda, 2022; Tang *et al.*, 2021; Archinect, 2020c); lack of privacy and proper work environment (home, dormitory etc.) (Ceylan *et al.*, 2021; Ibrahim *et al.*, 2021; Peimani and Kamalipour, 2021b; Bakir and Alsaadani, 2022); lack of emotional connection (Alnusairat *et al.*, 2021); lack of guidance and support (Alnusairat *et al.*, 2021; Asadpour, 2021); insufficiency of self-discipline and concentration issues (Peimani and Kamalipour, 2021a; Varma and Jafri, 2021; Tandon *et al.*, 2021; Ibrahim *et al.*, 2021; Wu *et al.*, 2021); low interaction and communication issues among students and between students and instructors (Alnusairat *et al.*, 2021; Tandon *et al.*, 2021; Varma and Jafri, 2021; Elrawy and Abouelmagd, 2021; Tang *et al.*, 2021; Peimani and Kamalipour, 2021b;

Impact	Sub-category	Subfactor	Number of sources
Challenges	Students' experience with online education during pandemic	Lack of fast and stable Internet connection	15
		Issues with the availability of up-to-date and appropriate hardware and software platforms	13
		Low interaction and communication issues among students and between students and instructors	8
		Time and workload management (i.e. an increase in the number of tasks)	7
		Psychological problems/negative feelings that could lead to alienation, uncertainty, confusion, and identity loss	7
		Increased sense of isolation, and disconnection from peers and colleagues	6
		Insufficiency of self-discipline and concentration issues	5
		The difficulties in understanding teachers' instructions online	5
		The lack of privacy and a proper work environment (home, dormitory etc.)	4
		Technical issues	3
		Instructors' inability to integrate technology or insufficient software skills (which influences the efficiency of the course)	3
		The need for user-friendly interfaces and applications to make e-learning easy	2
		The focus on learning the technology rather than on the information taught	2
		Students' lack of necessary computer skills to work on their design projects	2
		Lack of guidance and support	2
	The emergence of cyber security risks	1	
	The lack of emotional connection	1	
	Increased boredom (due to too many tasks)	1	
	Technological complexity	1	
	Lack of an adequate technical background to solve networking and software related issues	1	
	Limited signal strength and limited gadget capabilities	1	
	Transition and adoption of online AE	Student assessment issues	8
		Lack of access to resources	7
		Lack of skills to utilize devices or facilities (the need for more time and practice to use new software and applications)	3
		Reluctance to use the camera	3
		Challenges to academic integrity management and assessment security	2
		The dissolved boundaries between the work environment and home environment (i.e. struggle with establishing boundaries between work and family)	2
		Concerns about cheating	1
		Extended working hours for instructors	1
		Less effective student discussions	1
		Inability to use sophisticated technology	1
		Expectation from students to be more responsible for their own education	1
		Blended learning	Lack of peer learning
Inadequacy of critique frequency and quantity	3		
Increased time spent on lectures and design critiques	2		
Technologically produced designs can be too stereotypical (i.e. lower creativity)	2		
Inability to explain design ideas online	2		
Lack of tutor's proficiency for virtual design training	2		
AE pedagogy and curriculum development	Tutor's inability to convey feedback virtually	1	

Table 7.
The negative impacts of COVID-19 on architectural education

Impact	Subcategory	Subfactor	Number of sources	COVID-19's impact on architectural education
Benefits	Students' experience with online education during pandemic	Removal of geographic barriers	10	
		Opportunity to access recorded lectures and juries at any time	8	
		Elimination of time constraints	4	
		Alternative communication methods (Zoom, itslearning, Skype, etc.)	3	
		Opportunity to improve computer skills	2	
		Flexibility to run the applications on a variety of devices (e.g. mobile devices, tablets, and laptops)	1	
		Opportunity to simplify the organization of meetings and lectures	1	
		Ability to allow an unlimited number of participants to participate in courses	1	
		Ability to revisit discussed material in lectures or sessions through the chat history	1	
		Transition and adoption of online AE	A decrease in both the expenses for printing and its impact on the environment	3
		Providing flexibility	2	
		More time to focus on actual teaching and learning activities rather than on organizing suitable physical spaces on campus	1	
	Blended learning	Opportunity to improve AE with online technologies	6	
		Allowing "blending" of the benefits of synchronous critiques and asynchronous learning	4	
		Providing a balanced format that includes both virtual and physical teaching aspects	3	
	AE pedagogy and curriculum development	Enabling students to discover their potential and develop their abilities	10	
		The potential of collaborating with institutions and professionals all around the world	4	
		Opportunity to make students participate and change their role from passive to active	1	

Table 8.
The positive impacts of COVID-19 on architectural education

Ibrahim *et al.*, 2021; Al Maani *et al.*, 2021); time and workload management (i.e. an increase in the number of tasks) (Alnusairat *et al.*, 2021; Tandon *et al.*, 2021; Varma and Jafri, 2021; Ibrahim *et al.*, 2021; Andiyan *et al.*, 2021; Bakir and Alsaadani, 2022; Al Maani *et al.*, 2021); increased boredom (due to too many tasks) (Andiyan *et al.*, 2021); issues with the availability of up-to-date and appropriate hardware and software platforms (Ibrahim *et al.*, 2021; Asadpour, 2021; Alnusairat *et al.*, 2021; Milovanović *et al.*, 2020; Varma and Jafri, 2021; Elrawy and Abouelmagd, 2021; Tang *et al.*, 2021; Peimani and Kamalipour, 2021b; Andiyan *et al.*, 2021; Gambo and Musonda, 2022; Salama and Crosbie, 2020; Salama, 2020; Gloster, 2020; Archinect, 2020b); lack of an adequate technical background to solve networking and software-related issues (Tandon *et al.*, 2021); need for user-friendly interfaces and applications to make e-learning easy (Tandon *et al.*, 2021; Alnusairat *et al.*, 2021); emergence of cyber security risks (Peimani and Kamalipour, 2021a); limited signal strength and gadget capabilities (Andiyan *et al.*, 2021); instructors' inability to integrate technology or insufficient software skills (which influences the efficiency of the course) (Megahed and Hassan, 2022; Asadpour, 2021; Peimani and Kamalipour, 2022); students' lack of necessary computer skills to work on their design projects (Ibrahim *et al.*, 2021;

Andiyan *et al.*, 2021) and a focus on learning the technology rather than on the information taught (Tandon *et al.*, 2021; Peimani and Kamalipour, 2021b).

Problems in transition to and adoption of online AE. The notable challenges in the transition to online AE include lack of skills to utilize devices or facilities (the need for more time and practice to use new software and applications) (Alnusairat *et al.*, 2021; Varma and Jafri, 2021; Andiyan *et al.*, 2021); dissolved boundaries between work and home environments (i.e. struggle with establishing boundaries between work and family) (Megahed and Hassan, 2022; Ibrahim *et al.*, 2021); challenges to academic integrity management and assessment security (Peimani and Kamalipour, 2021a, b); concerns about cheating (Ibrahim *et al.*, 2021); student assessment issues (Tandon *et al.*, 2021; Megahed and Hassan, 2022; Andiyan *et al.*, 2021; The Second Studio Podcast, 2020; Gloster, 2020; Archinect, 2020c; Bernstein, 2020; Khan and Thilagam, 2022); lack of access to resources (Alnusairat *et al.*, 2021; Bakir and Alsaadani, 2022; Khan and Thilagam, 2022; Archinect, 2020b; Grover and Wright, 2020; Salama and Crosbie, 2020; Gloster, 2020); reluctance to use the camera (Peimani and Kamalipour, 2021b, 2022; Bakir and Alsaadani, 2022) and extended working hours for instructors (Megahed and Hassan, 2022).

Challenges of blended learning. The significant negative effects on AE in the context of blended learning include inability to use sophisticated technology (Peimani and Kamalipour, 2022); less-effective student discussions (Peimani and Kamalipour, 2022) and expectation from students to be more responsible for their own education (Peimani and Kamalipour, 2022).

AE pedagogy and curriculum development. The most outstanding factors in this scope include increased time spent on lectures and design critiques (Megahed and Hassan, 2022; Koh and Wong, 2021); lack of peer learning (Peimani and Kamalipour, 2021b, 2022; Megahed and Hassan, 2022; Salama and Crosbie, 2020; Grover and Wright, 2020; Gloster, 2020); inadequacy of critique frequency and quantity (Asadpour, 2021; Alnusairat *et al.*, 2021; Al Maani *et al.*, 2021); technologically produced designs being more stereotypical (i.e. lower creativity) (Tandon *et al.*, 2021; Elrawy and Abouelmagd, 2021); inability to explain design ideas online (Asadpour, 2021; Archinect, 2020c); lack of tutor's proficiency for virtual design training (Asadpour, 2021; Khan and Thilagam, 2022) and tutor's inability to convey feedback virtually (Asadpour, 2021).

4.2.2.2 Positive impacts: a new perspective. COVID-19 has also had positive and beneficial impacts on AE and may assist the education ecosystem in growing more quickly, becoming more productive and more adaptable for future crises. Table 8 lists 18 positive factors obtained from the selected sources under the four subcategories.

Students' positive experience with online education during pandemic. New possibilities have arisen because of the shift toward distance education and extensive use of technology in AE. In the scope of the students' experiences, the most important changes include removal of geographic barriers (Tandon *et al.*, 2021; Ibrahim *et al.*, 2021; Peimani and Kamalipour, 2021a; Milovanović *et al.*, 2020; Megahed and Hassan, 2022; Komarzyńska-Świeściak *et al.*, 2021; Khan and Thilagam, 2022; Archinect, 2020a, b, c); elimination of time constraints (Tandon *et al.*, 2021; Varma and Jafri, 2021; Peimani and Kamalipour, 2021a; Archinect, 2020c); opportunity to access recorded lectures and juries at any time (Ceylan *et al.*, 2021; Tandon *et al.*, 2021; Alkhalil *et al.*, 2021; Peimani and Kamalipour, 2021a; Bakir and Alsaadani, 2022; Güler, 2022; Al Maani *et al.*, 2021; Grover and Wright, 2020); ability to allow an unlimited number of participants to participate in courses (Milovanović *et al.*, 2020); flexibility to run the applications on a variety of devices (e.g. mobile devices, tablets and laptops) (Alnusairat *et al.*, 2021); opportunity to simplify the organization of meetings and lectures (Komarzyńska-Świeściak *et al.*, 2021); opportunity to improve computer skills (Alnusairat *et al.*, 2021; Peimani and Kamalipour, 2022); ability to revisit discussed material in lectures or sessions

through the chat history (Peimani and Kamalipour, 2021a) and alternative communication methods (Zoom, itslearning, Skype, etc.) (Ceylan *et al.*, 2021; Archinect, 2020a, b).

Positive reflections of transition to online AE. The new normal of AE has generated positive results in its transformation. In this regard, the apparent and evident influences are: a decrease in both the expenses for printing and its impact on the environment (Alnusairat *et al.*, 2021; Tandon *et al.*, 2021; Al Maani *et al.*, 2021); flexibility (Tandon *et al.*, 2021; Megahed and Hassan, 2022) and more time to focus on actual teaching and learning activities rather than on organizing suitable physical spaces on campus (Peimani and Kamalipour, 2021a).

Blended learning opportunities. The current situation has improved educational outcomes, particularly for students, by introducing new learning approaches, such as hybrid methods. The most outstanding factors in this scope include: providing an opportunity to improve AE with online technologies (Megahed and Hassan, 2022; Megahed and Ghoneim, 2022; Khan and Thilagam, 2022; Al Maani *et al.*, 2021; Ibrahim *et al.*, 2021; Varma and Jafri, 2021); allowing “blending” of the benefits of synchronous critiques and asynchronous learning (Varma and Jafri, 2021; Megahed and Hassan, 2022; Megahed and Ghoneim, 2022; Archinect, 2020a) and providing a balanced format that includes both virtual and physical teaching aspects (Megahed and Hassan, 2022; Megahed and Ghoneim, 2022; Komarzyńska-Świeściak *et al.*, 2021).

New perspective on AE pedagogy and curriculum development. From our analysis of papers on AE pedagogy, the most prominent and clear impacts include enabling students to discover their potential and develop their abilities (Ceylan *et al.*, 2021; Alnusairat *et al.*, 2021; Asadpour, 2021; Elrawy and Abouelmagd, 2021; Tandon *et al.*, 2021; Bakir and Alsaadani, 2022; Al Maani *et al.*, 2021; Peimani and Kamalipour, 2022; Khan and Thilagam, 2022; Gloster, 2020); opportunity to make students participate and change their role from passive to active (Asadpour, 2021) and potential of collaborating with institutions and professionals from around the world (Megahed and Hassan, 2022; Komarzyńska-Świeściak *et al.*, 2021; Khan and Thilagam, 2022; Archinect, 2020c).

4.2.3 Analysis of mitigation strategies. Based on the numerous mitigation methods addressed in the selected documents, a mitigation framework was proposed. In total, 30 publications and other sources in our dataset recommended various mitigation actions to minimize the pandemic's negative impact on AE and make it more resilient to future crises. Approximately 44 distinct mitigation strategies were obtained. These were divided into four categories as follows: ensuring students' positive experience with online education during the pandemic, transition to and adoption of online AE, blended learning and AE pedagogy and curriculum development as presented in Table 9.

5. Discussion

In this study, science mapping was used to discover influential authors, institutions, articles and keywords related to the COVID-19 pandemic and AE. Our findings highlight the status and development tendencies in AE during COVID-19. The analysis revealed the knowledge base and enhanced the understanding of the intellectual structure of the research field. Owing to the COVID-19 pandemic, online AE is a fast-evolving research area attracting considerable interest from researchers regarding the challenges, benefits, mitigation measures and adaptation to this new normal. Unlike previous research, this study revealed four significant current issues about AE during the pandemic and projections for its future: (1) students' experience with online AE during the pandemic, (2) transition and adaptation to online AE, (3) blended learning and (4) AE pedagogy and curriculum development. Additionally, across the sampled papers, prospects for the future of AE research repeatedly included the same trending research topics.

Category	Mitigation measure
Students' experience with online education during pandemic	<p>Fast, affordable and secure Internet is accessible to all</p> <p>Providing licensed software</p> <p>Providing licensed platform</p> <p>Providing hardware like tablets and computers</p> <p>Upgrading the microphones of instructors</p> <p>Providing technical guidance</p> <p>Providing training on distance tools for students and staff</p> <p>Psychological support for the students and staff</p> <p>Medical support for students and staff</p> <p>Adding tutorials to address/answer questions</p> <p>Conducting one-to-one discussions between the instructor and the student</p> <p>Goals and expectations should be clearly expressed</p> <p>Visual timetables and intermittent individual follow-up communication should be ensured</p> <p>Peer, emotional, social, and economic support</p> <p>Conducting COVID-19 prevention seminars</p> <p>Establishing a psychological counseling hotline</p> <p>Evolving a comprehensive feedback loop on diverse issues</p> <p>The online courses should be separated into sub-modules, and key parts should be highlighted with visuals and videos to aid with self-pacing and backtracking</p> <p>Explaining the grading system to students</p> <p>Online platforms ought to offer students more opportunities to obtain knowledge</p> <p>Explaining how the students will be assessed, and demonstrate the requirements and responsibilities expected of them</p>
Transition and adoption of online AE	<p>Redefine e-studio contents, procedures, and outcomes</p> <p>The shift to small classes instead of large studios</p> <p>Choosing suitable online course platforms</p> <p>Question-guided teaching strategy</p> <p>Continuous ongoing evaluation and improvements</p> <p>Enabling students to acquire e-learning habits</p> <p>Employing specific project teams to provide adequate training to teaching fraternity to make e-learning more interactive, interesting and motivating</p> <p>Bringing flexibility in curriculum development</p> <p>Improving content quality</p> <p>Following a step-by-step procedure – systematic plan (to offer a high-quality course)</p> <p>Priority should be given to pedagogy over technology</p>
Blended learning	<p>Systemically training educators</p> <p>Choosing course content that best suits the students' levels of knowledge, experience, and ability</p> <p>Conducting a detailed analysis and interpretation before starting the course</p> <p>Teaching students how to become active and self-directed learners (setting them up for long-term independent success)</p>
AE pedagogy and curriculum development	<p>Decrease the workload of online design classes</p> <p>Increasing the frequency of feedback</p> <p>Developing new teaching methods for e-learning that may be as effective as face-to-face learning</p> <p>Short-term workshops and courses for students and faculty members</p> <p>The e-studio should be used to build a new network of relationships rather than just academic topics</p> <p>Providing the students with live projects, gamifying the quizzes and other assignments</p> <p>Setting a time to discuss side issues in the e-studio</p> <p>Transferring experiences between architectural colleges and schools – filling gaps in other universities and improving the sense of empathy</p>

Table 9.
Analysis of mitigation strategies

5.1 Regarding the students' experience with online AE during pandemic

A lasting effect of the COVID pandemic on AE has been a shift from the traditional design studio to virtual studios, where remote and asynchronous learning has replaced synchronous interactions. Instructions are delivered through online materials, and students can share their work, at any stage of development, through digital documents, without being restricted by the physical boundaries of the design studio (Al-Qawasmī, 2005). They can think “fluidly” and generate multiple designs quickly. However, assessment and quality feedback from instructors before submissions is difficult. Additionally, due to the global nature of digital applications, students' designs may not suit the sociocultural contexts of their regions. Thus, in design learning, there is a need to move away from a narrow technical perspective and develop inclusive and customizable digital design tools (Soulikias *et al.*, 2021).

Grover and Wright (2020) reported that students' overall satisfaction decreased by 58% following their move to online education in the National Design Studio Survey. Milovanović *et al.* (2020) mentioned that poor Internet service, lack of necessary equipment and/or financing and difficulty in using new technology are obstacles in the adoption of online learning (Asadpour, 2021). These factors, as well as instructors' inexperience in online teaching, were the most important concerns regarding online design studios (Alnusairat *et al.*, 2021). Technological challenges, uncertainties about aspects of design education and a lack of guidance and support are issues faced by students when learning online (Al Maani *et al.*, 2021). First- and second-year architecture students may still be accustomed to teacher-centric educational models. Therefore, flexible studios are recommended for younger students, allowing for direct contact with tutors when needed and opportunities to attend discussions and reviews (Al Maani *et al.*, 2021; Bakir and Alsaadani, 2022).

5.2 Regarding transition and adaptation to online AE

Adaptation and mitigation procedures are required as AE passes through this pandemic-related “transitional emergency model.” Critical problems have arisen due to this situation: lack of access to high-speed Internet and off-campus availability of licensed software or specialized computers for modeling and visualization; lack of support for students facing online restrictions; home settings not conducive to teaching for many instructors and severely limited internships, co-op programs and training opportunities (Salama and Crosbie, 2020). According to the Royal Institute of British Architects (RIBA) COVID-19 Student Survey (Gloster, 2020), only certain curriculum sections in architecture education are appropriate for online teaching and learning; therefore, vital planning for the digital future is needed (RIBA, 2020). A school's success in adapting to constraints and challenges relies on the strength and flexibility of its community (Archinect, 2020a). In addition, the decision-makers at architecture schools must recognize that the situation brought about by the pandemic is irreversible and adapting to it is the only path forward. Change, flexibility and adaptation must now be a part of curriculum structure. New teaching and learning processes and design studio practices must be adopted (Salama and Crosbie, 2020).

5.3 Blended learning is another significant issue encountered with the pandemic

Online learning cannot provide a peer-to-peer learning environment, dynamic interactions that are possible at design studios and face-to-face seminars and discussions that are considered essential for AE. Activities such as hand drawings and rendering exercises or those that require artistic media cannot be performed online (Bender and Vredevoogd, 2006; Chen and You, 2010; Salama and El-Attar, 2010). The shift toward online and blended learning in AE was being planned for years before the pandemic started (Ceylan *et al.*, 2021). Augmented design studios have been used in the past (Bender and Vredevoogd, 2006; Ioannou, 2018; Morozumi *et al.*, 2001; Niculae, 2011; Rodriguez *et al.*, 2018; Schnabel and Ham, 2012). According to research, AE could

be enhanced by using blended learning with online technologies (Al Maani *et al.*, 2021; Ibrahim *et al.*, 2021; Varma and Jafri, 2021). These approaches assist with the current pandemic situation and also provide the opportunity for cross-departmental or multidisciplinary collaborative educational sessions. The COVID-19 pandemic has accelerated the adoption of these approaches and forced course and curriculum changes across campuses.

5.4 AE pedagogy and curriculum redevelopment

The transition of AE from in-person to online teaching because of the pandemic also requires a rethinking of the existing curriculum and instruction in architecture undergraduate programs (Varma and Jafri, 2021; Archinect, 2020b). A new blended learning AE framework could be considered, given the availability of good visualization and communication software and the relative ease of digitalization of data for online teaching (Varma and Jafri, 2021). This would require alternative methods for conceiving, delivering and evaluating architectural assignments. A global perspective on online teaching should be brought in to redesign the curriculum, instruction methodology and administrative aspects of AE for the post-pandemic future (Saghafi *et al.*, 2012; Masdéu and Fuses, 2017). Based on the availability of resources, institutions should have the autonomy to offer hybrid learning that provides students the options to choose physical/virtual spaces, synchronous/asynchronous content delivery, self-paced or programmed courses, communication platforms, feedback mechanisms and assessment methods (Varma and Jafri, 2021).

5.5 Trend research topics

Although online AE is not a new idea, it has accelerated in the last two years due to the pandemic's extraordinary conditions. As presented in Section 4.5.2 and Figure 4, AE research has evolved from understanding and adopting online AE to proposing new educational approaches for the future of AE, which include instructional systems. The adoption of online learning due to the COVID-19 outbreak has forced educational departments to rethink the curricula and pedagogy and also the basic purpose of education. Blended learning requires redesign, preparation and adequate online support for successful learning and teaching, making it time-consuming and expensive. Thus, a detailed syllabus and cost analysis must be done to determine whether it can be adapted for blended learning (Megahed and Hassan, 2022).

A systematic reorganization and integration of content, pedagogy and knowledge are needed to maximize the role of technology in blended learning. With the progress in digitalization of data and availability of visualization and communication software, a new approach to include blended learning in AE is required (Varma and Jafri, 2021).

The key to successful online learning is the course design, availability of learning materials and instructions and effective interaction between the students and lecturers (Wang *et al.*, 2018). The focus should be on creating engaging content and teaching mode rather than only on technology (Donitsa-Schmidt and Topaz, 2018; Koh and Wong, 2021). AE instructors should emphasize instructional models and taxonomies for effective technology integration. Some resources for designing an effective blended learning environment are Technological pedagogical content knowledge (TPACK), Bloom's Taxonomy and BL matrices and continuum (Megahed and Hassan, 2022). Instructors must investigate and master specific models.

6. Research implications

The COVID-19 pandemic has presented an opportunity to consider different education methods for AE (online and blended education), which will mitigate the adverse effects of the

current COVID-19 and also increase the preparedness of architectural schools. The case of online education for AE is complicated because most design (studio) courses, as part of course requirements, demand some type of residency component, which is not met in online teaching. Therefore, innovative AE is imperative.

Architectural schools must become adaptive systems for the post-pandemic future. Schools should rethink their curricula, resources and flexibility in addressing unexpected situations (Allam *et al.*, 2020). Learning formats and studio design forms should be adaptable to hybrid or virtual environment. It is known that senior students could adapt to virtual studios more easily. Employing VR technology within architectural design pedagogy can offer solutions to some online education challenges.

Increasing the use of educational technology (e.g. Edtech) may prove beneficial. Edtech tools, such as Wiki pages, discussion boards, online whiteboards, screen-casting, collaborative content creation, web-based platforms, collaborative word processing and online chat rooms, are easily available and can facilitate collaborative learning.

Knowledge of students' experiences and perceptions of online learning should help instructors enhance their preparation of educational content and its delivery by allowing students to take responsibility for their own design learning (Iftikhar *et al.*, 2021). In addition, consistent and effective feedback to and from students will ensure their satisfaction and improve the delivery of online courses.

Accordingly, in future developments of architectural pedagogy, online teaching should be featured as a component to allow an "individualized" approach for remote teaching. Greater investment may be needed to foster tailored patterns that may accommodate the specific needs and conditions of students' divergent learning stages within their educational journey, providing suitable and alternate educational technologies that support self-learning and the delivery of beneficial and effective feedback to ensure continuous student satisfaction and engagement.

The implications of the results of this study also extend to the post-pandemic future; they may provide ample guidance for architectural educators who seek to transition from a temporary, pandemic-related arrangement to a long-lasting, robust platform for distance learning that serves as the new normal of education and helps educators achieve the logistical goals of academic institutions.

7. Conclusions

The effects of the COVID-19 pandemic on AE have raised the interest of numerous academics worldwide, who have investigated them using a variety of research approaches and strategies. This study focused on analyzing the problems posed by the pandemic, as well as applying creative approaches and technologies to address these new situations in the AE environment. Aside from the adverse effects, the pandemic has provided some opportunities and new avenues for improving education pedagogy.

We used both bibliometric and content analyses to obtain insights into literature on the effects of the pandemic on AE. Using bibliometric analysis, we discovered the most productive authors, universities, countries and key tendencies from the number of citations and publications. In addition, VOSviewer tools were used to create a graphical representation of the bibliometric data from the co-authorship of authors, countries and universities and co-occurrence of keywords. A comprehensive understanding of a specific field of study can be obtained from bibliometric analysis. This analysis shows that Hesam Kamalipour and Nastaran Peimani are the most productive authors with three publications each. A detailed analysis of countries enabled us to find that Egypt, Jordan and India, respectively, are the top three countries contributing to research on AE and the COVID-19 pandemic. In addition, the visualization of the co-occurrence of the keywords helped us discover the links and their

strengths between the interconnected communities in the domain of AE during the pandemic research, and four significant clusters were determined.

Content analysis provided a classification of the main research topics. The negative and positive impacts of the current pandemic on AE were determined. The study also proposes a four-dimensional mitigation framework, which includes advice such as new guidelines, students' experience with online AE during the pandemic, transition and adaptation to online AE, blended learning, AE pedagogy and curriculum development.

This study contributes to the body of knowledge by presenting an overview of the effects of the COVID-19 pandemic on AE. From a theoretical perspective, understanding the pandemic's current effects on AE could provide a range of ideas in terms of the steps required to ensure that the educational ecosystem completely recovers. In addition, this study contributes to the development of new literature on AE specific to COVID-19 as well as possible future crises. From the perspective of practical implementation, the findings of this research can aid higher education institutions in identifying and mitigating the negative effects of the pandemic on AE and preparing them for any future crises.

This study also has several limitations, which will be addressed in future research. The first is the research period (2020–June 2022). We anticipate that due to the changing nature of AE, new subjects, concepts and approaches may be introduced, which may significantly alter the findings of this study. Moreover, as the study is based on data acquired from the WoS database, the limitations of this database may apply to this study as well. Therefore, future studies should use other databases, such as Scopus and Science Direct, or a combination of databases.

Finally, we may transition to online and/or hybrid education models as variants of the coronavirus or forthcoming crises emerge, making the findings of this research more relevant. The outcomes of this study also provide a direct insight into the process of online education, which may help inform a better virtual ecosystem that is necessary for the future development of AE.

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