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Virtual education in the rural sector: analysis of scientific literature

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Introduction: The advent of the pandemic has led to a surge in the popularity of virtual education in rural areas, offering the potential to bridge the access gap. Despite the opportunities provided by digital transitions, challenges persist in regional educational events, requiring differentiated approaches. The lack of accurate information justifies the need for research, particularly to analyze and address neglected areas. This study aims to explore research trends in the field.

Methods: A bibliometric analysis was conducted following the PRISMA-2020 statement, using data from the Scopus and Web of Science databases.

Results: The findings indicate exponential growth in research, with 2021 and 2022 being the most prolific years. Key references include the author Wang J, the journal Computers & Education, and leading research contributions from the United States and India. Thematic evolution suggests a shift towards topics such as professional learning, mental health, and public health. The keyword co-occurrence network highlights thematic clusters related to e-learning, information and communication technology (ICT), and teacher training.

Discussion: The analysis of keyword validity and frequency reveals emerging concepts like rural health and digital inclusion, alongside established themes such as education. This study provides a detailed understanding of the research landscape on virtual education in rural areas, identifying areas of interest and emerging trends.

KEYWORDS

events, challenges, transition, PRISMA-2020, access

1 Introduction

The topic of virtual education in the rural sector has become a subject of interest, particularly in the wake of the global pandemic that forced a rapid transition from face-to-face to digital teaching. This educational modality has the potential to bridge the gap in access to and educational equity in quality education in rural areas, where geographic limitations and a lack of infrastructure can impede the provision of in-person education. The implementation of virtual learning platforms can provide rural students with access to educational resources and opportunities for learning that would otherwise be inaccessible (Wang et al., 2019).

The forced shift toward virtual education has posed significant challenges but has also revealed opportunities to improve educational inclusion. In one study, the learning experiences and expectations about changes in education of nursing students enrolled in the Bachelor's and Master's degrees of two Spanish public universities during the first month of confinement

due to the COVID-19 pandemic were sought to be understood. The qualitative study was conducted during the initial phase of the state of alarm in Spain (from March 25 to April 20, 2020). The study concluded that online education transcends the mere continuation of face-to-face classes, and that work should be done on this matter, given the uncertain future in the short-term control of the novel coronavirus (Ramos-Morcillo et al., 2020). Other research conducted in China with children and adolescents demonstrated that confinement and online education may be associated with feelings of anxiety and depression, underscoring the necessity for adequate emotional support during these transitions (Liu et al., 2021).

In the context of rural communities, virtual education can be employed as a tool for the development of specific skills. The teaching of digital literacy skills to older individuals in rural areas can be facilitated through the use of social networks with linear navigation. This initiative not only improves digital skills but also promotes social inclusion and active participation in the digital community (Castilla et al., 2018).

Moreover, the acceptance of mobile learning in rural areas for the teaching of science, technology, engineering, and mathematics (STEM) has demonstrated potential. Several factors influence the acceptance of mobile education in these areas, including positive attitudes toward technology and the perception of its usefulness. Mutambara and Bayaga (2021) proposes that the use of cloud-based virtual learning environments may be a solution to mitigate academic disparities between urban and rural students. These environments provide access to high-quality educational resources and promote educational equity (Safdar et al., 2022).

It is crucial to distinguish between various terms associated with virtual education, such as digital education, digital teaching, online education, mobile learning, distance education, and remote education. While these terms are related, they are not equivalent and refer to specific modalities and methodologies. Digital education encompasses the use of digital technologies in the teaching and learning process, while digital teaching focuses on the application of digital tools and resources to impart knowledge (Kadirbergenovna, 2022). Online education is defined as the delivery of instruction and learning experiences via the Internet, utilizing online platforms and resources (Williamson et al., 2020).

In contrast, mobile learning is defined as the use of mobile devices to access educational materials and participate in learning activities, which allows for greater flexibility and accessibility (Criollo-C et al., 2021). Distance education is defined as a mode of education in which students and instructors are not physically present in the same location, and in which various means of communication are employed to facilitate interaction (Ramos-Morcillo et al., 2020). The popularity of remote education has increased significantly during the COVID-19 pandemic. This modality of teaching, which is conducted remotely and employs digital technologies, has emerged as a response to the unfeasibility of face-to-face education (Williamson et al., 2020).

In recent years, the education sector has undergone a significant transformation, necessitating a corresponding transformation in traditional teaching methods, particularly in rural areas where educational infrastructure and resources are often limited. Virtual education offers a promising solution for overcoming these barriers and ensuring equitable access to education. The perceptions of students in remote areas during the pandemic were investigated, revealing that, despite technical and connectivity challenges, online

education was perceived positively by students. This was the case for students of different educational levels (Harefa and Sihombing, 2022).

In Nepal, the impact of the pandemic on the education system further highlighted the necessity for digital educational solutions. Virtual education can provide educational continuity in times of crisis and offers future perspectives for improving educational accessibility and quality in rural areas. The pandemic has highlighted the necessity to adapt and enhance technological infrastructure and to educate educators and students on the full potential of virtual education (Pal et al., 2021).

The significance of virtual education is also reflected in studies on social media learning and the adoption of mobile technologies. A comparison of rural and urban regions in Uganda revealed that social media can be an effective tool for learning and the adoption of mobile technologies, such as mobile money. This not only facilitates digital literacy but also promotes financial inclusion, demonstrating how virtual education can have a broad and positive impact on rural communities (Kiconco et al., 2020).

In Colombia, virtual education has encountered specific challenges in the context of higher education programs, with a particular focus on the influence of rurality on dropout rates. This has led to an analysis of the necessity for personalized strategies to support rural students and reduce dropout rates (Guzmán Rincón et al., 2021). In Indonesia, the significance of device ownership and technological infrastructure for the success of e-learning and m-learning was underscored, demonstrating that while virtual education presents challenges, it also offers a viable solution to improve education in rural areas, contingent upon the adequate addressing of technological and social barriers (Pratama and Scarlatos, 2020).

In recent years, virtual education in rural contexts has gained significant relevance due to the need to reduce disparities in access to quality education (Kulal et al., 2024; Wang et al., 2024). A longitudinal analysis of the impact of virtual schools in rural areas was conducted by Hamlin et al. (2023), who found that while these initiatives expand educational coverage, challenges remain in terms of academic performance and equitable access to digital resources. Similarly, Guerrero-Casquete et al. (2023) examined the impact of the COVD-19 pandemic on rural education, highlighting that the rapid transition to virtual learning exposed critical gaps in technological infrastructure and internet connectivity. These studies underscore the urgency of designing strategies that not only implement online learning platforms but also enhance teacher training and resource availability to ensure effective and equitable education in rural areas.

The integration of Information and Communication Technology (ICT) competencies in rural education has become a key focus in recent research. Gaitán and Pérez (2024) conducted a descriptive study on ICT training among teacher education students, revealing the need to strengthen digital skills development for future educators in rural settings. The lack of training in the pedagogical use of technology represents a major barrier to the successful implementation of virtual education in these regions. Consequently, further exploration of strategies for teacher training and enhanced digital infrastructure is imperative to ensure that virtual education becomes an effective tool for educational inclusion in rural areas.

The existing body of literature on this topic is severely lacking, underscoring the necessity for further studies in this field. The majority of existing research has focused on urban contexts or well-equipped educational environments, often overlooking the distinctive

characteristics and challenges faced by these communities. The necessity for the development of specific and analytical approaches tailored to the unique circumstances of rural communities has been identified. However, the implementation of advanced technologies in these regions remains insufficiently explored. This indicates a lack of comprehensive understanding of how virtual education can be adapted and optimized for rural conditions (Tosida et al., 2022).

Although studies have been conducted on motivation and academic performance during the COVID-19 pandemic, they do not always address the significant differences between urban and rural students. Research tends to focus on populations with better access to technological and educational resources. This creates a gap in knowledge about the needs and experiences of rural students (Suraj et al., 2024). Furthermore, challenges in conference participation and educational events were identified for specific regions, reflecting the need for differentiated regional approaches (Page and Mosen, 2024).

The absence of reliable data necessitates the conduct of this study, which aims to analyze existing research, identify gaps in knowledge, and provide a robust foundation for future research that effectively addresses educational needs in the rural sector. Consequently, the objective of this study is to analyze research trends in virtual education in the rural sector through a bibliometric approach. Specifically, it aims to identify the periods of highest scientific production, the main authors and reference sources, the predominant and emerging themes, as well as the collaboration networks among researchers and institutions. Through this analysis, the study seeks to provide a clear understanding of the field's evolution, highlighting challenges and opportunities for future research in virtual education in rural contexts, the following research questions have been formulated:

- What are the years in which there has been the greatest interest in virtual education in the rural sector?
- What is the nature of the growth in the number of scientific articles on virtual education in the rural sector?
- What are the main research references on virtual education in the rural sector?
- What are the overarching themes that emerge from the scientific literature on virtual education in the rural sector?
- What are the principal thematic clusters pertaining to virtual education in the rural sector?
- What are the most prevalent and emerging keywords in the field of virtual education in the rural sector?
- What themes should be prioritized in the design of a research agenda on virtual education in the rural sector?

2 Methodology

An exploratory type of research is conducted based on secondary research sources, employing a bibliometric analysis to evaluate the extant literature on virtual education in the rural sector. This study adheres to the parameters established in the PRISMA-2020 declaration, which guarantees transparency in data collection and synthesis. The PRISMA-2020 statement provides updated guidelines for the preparation of systematic reviews, ensuring exhaustiveness and clarity in the reporting of findings. These guidelines permit a critical and structured evaluation of scientific publications, thereby facilitating the identification of trends, gaps in research, and areas of opportunity

in the field of virtual education in rural environments (Page et al., 2021).

2.1 Eligibility criteria

The inclusion criteria for this study were based on the selection of titles and keywords as the main metadata. In order to identify relevant documents that address the intersection between virtual education and rural areas, a search for terms related to "virtual education" and "rurality" was conducted. This search was combined with an examination of the various ways in which these concepts can be referred to in literature. The strategy allowed for the identification of relevant documents that address the intersection between virtual education and rural areas, ensuring that a broad spectrum of relevant research is covered.

The exclusion process is conducted in three phases. In the initial phase, all records that have erroneous indexing are excluded, ensuring the accuracy of the data collected. In the second phase, all documents for which there is no access to the full text are excluded. However, this phase applies exclusively to systematic literature reviews and not to bibliometrics, since the latter only analyzes metadata. In the third phase of the exclusion process, documents are excluded that have incomplete indexing, conference proceedings, and those that are deemed to be of little relevance to the study.

2.2 Source of information

In this research, the Scopus and Web of Science databases were selected as the main academic databases, as they are considered the most comprehensive and reliable sources of information in the field of academic research. These platforms provide extensive coverage and high-quality bibliographic records, making them essential tools for bibliometric studies. Both Scopus and Web of Science offer extensive citation indexes and multidisciplinary coverage, ensuring the inclusion of a wide range of relevant studies and guaranteeing the reliability and comprehensiveness of the bibliometric analysis carried out. It is of the utmost importance to obtain a comprehensive view of the state of research in virtual education in the rural sector. The choice of these databases ensures the inclusion of a wide range of relevant studies and guarantees the reliability and comprehensiveness of the bibliometric analysis carried out (Zhu and Liu, 2020).

2.3 Search strategy

Two bespoke search equations were devised, one for each database. The equations were developed with the intention of accurately capturing the relevant literature. Each equation incorporated specific terms and Boolean operators that were adapted to the structure and search functionalities of Scopus and Web of Science. This approach ensures the retrieval of relevant and high-quality documents.

The study focuses on the investigation of contributions to the topic of virtual education in rural areas. In order to give sufficient breadth to the search, concepts, methodologies and associated trends such as digital education, digital teaching, online education, mobile

education, distance education and education were included. However, completely homogeneous or identical concepts are not considered, in order to ensure the retrieval of relevant and high-quality documents.

For the Scopus database: ((TITLE ("Virtual education" OR "Online education" OR "Distance learning" OR "E-learning") AND TITLE ("Rural areas" OR "Rural communities" OR "Countryside" OR "Remote regions" OR "Outlying areas" OR "Villages" OR "Small towns")) OR (KEY ("Virtual education" OR "Online education" OR "Distance learning" OR "E-learning") AND KEY ("Rural areas "OR "Rural communities" OR "Countryside" OR "Remote regions" OR "Outlying areas" OR "Villages" OR "Small towns")))).

For the Web of Science database: ((TS = ("Virtual education" OR "Online education" OR "Distance learning" OR "E-learning") AND TS = ("Rural areas" OR "Rural communities" OR "Countryside" OR "Remote regions" OR "Outlying areas" OR "Villages" OR "Small towns"))).

2.4 Data management

In this study, Microsoft Excel® played a crucial role in the management, organization and analysis of bibliometric data obtained from Scopus and Web of Science. It was used to extract, clean and structure information such as publication years, authors, citation counts, keywords and institutional affiliations. Additionally, Excel facilitated descriptive statistical analysis, allowing researchers to calculate the annual growth rate of publications, identify the most influential authors and examine trends in research productivity. Beyond these functions, the software enabled collaboration analysis, mapping co-authorship networks between researchers and institutions. To enhance the study's analytical depth, VOSviewer® was employed to generate bibliometric maps that visually represent relationships within the dataset. This included co-occurrence networks of keywords, revealing thematic clusters, as well as co-authorship maps that identified collaboration patterns at both institutional and national levels. The software also facilitated the visualization of thematic evolution, illustrating how research in virtual education for rural areas has transitioned from early concerns, such as access barriers, to more contemporary topics like digital inclusion and e-learning methodologies (Van Eck and Waltman, 2010). By integrating Excel's quantitative capabilities with VOSviewer's advanced visual representations, the study provided a comprehensive and systematic analysis of scientific production, ensuring an insightful and structured presentation of research trends in this field.

2.5 Selection process

As outlined in the PRISMA 2020 guidelines, it is imperative to disclose the utilization of internal automation tools in the study selection process, in addition to the execution of internal or external validation to minimize the risk of missing studies or misclassifications (Guerrero-Casquete et al., 2023). In this study, Microsoft Excel® automation tools, developed by all participating researchers, were employed to apply the inclusion and exclusion criteria independently, thereby reducing the likelihood of errors and ensuring consistency in the selection process.

To maintain rigor and replicability, the selection of manuscripts followed a multi-stage process aligned with PRISMA-2020. Firstly, inclusion and exclusion criteria were established based on thematic relevance, ensuring a focus on virtual education in rural areas. A systematic search was conducted in Scopus and Web of Science using tailored search equations with key terms and Boolean operators. After removing duplicates, an initial screening was performed based on titles and abstracts. In the subsequent phase, the full text of the studies that had been preselected was reviewed to confirm their relevance and methodological quality. Finally, additional filters were used to exclude documents with incomplete indexing, conference proceedings, and studies that were misaligned with the research objectives. The process was conducted independently by multiple researchers, and the results were cross-checked to ensure accuracy and consistency.

2.6 Data collection process

It is crucial to delineate the methodologies employed to gather data from bibliographic reports, including the number of reviewers involved in data collection for each report, whether they operated independently, any procedures for obtaining or confirming data from study investigators, and details about the automation tools utilized in the process (Page et al., 2021). In the present study, Microsoft Excel® was employed as an automated tool for the data collection process of the reports obtained from the selected databases. All authors participated as reviewers in the validation process, conducting it independently. Subsequently, the data confirmation process was carried out collectively until absolute convergence in the results was achieved.

2.7 Data elements

In conducting this research, the results were sought out for all articles that responded to the research objective, which entailed compliance with the specialized search equation designed for each database. This equation required that all articles that mention virtual education in the sector, rural or otherwise, be included. However, if there is missing or unclear information, it will be excluded under the category of "non-relevant texts," as it does not contribute to an understanding of the basis of knowledge on the subject. This exclusion was made to guarantee consistency with the purpose and scope of the research, ensuring that only relevant data is included and that it contributes to the bibliometric analysis in a meaningful way.

2.8 Assessment of the risk of bias of the study

The evaluation of the risk of bias of the included studies was conducted by all authors, as was the data collection. This evaluation was carried out using the same automated Microsoft Excel® tool, which allowed standardization in the process and guaranteed the quality and integrity of the results obtained. Each participating author independently evaluated each included study, using predefined criteria established in the tool, which facilitated an objective and consistent assessment of the risk of bias in the literature revised.

2.9 Measures of effect

As this research is based on secondary research sources, effect measures typical of primary research, such as risk ratio or mean difference, are not applicable. Instead, more appropriate measures are used for analysis. These include bibliometric measures, such as the number of publications, the number of citations, and the temporality of use of each keyword. These measurements are obtained through the use of tools such as Microsoft Excel®, which allows the extraction and manipulation of data from databases selected. Tools such as VOSviewer® are also used, which allow the existing nodes in the bibliographic network to be analyzed to determine thematic associations between the studies. These tools facilitate the synthesis and presentation of collected information in a systematic and structured manner.

2.10 Synthesis methods

A series of processes were carried out to determine the eligibility of the studies for each synthesis. These included the tabulation of relevant characteristics of the study intervention and their comparison with the groups planned for each analysis. Additionally, methods were used to prepare the data for presentation or synthesis. This involved handling missing summary statistics or necessary data conversions. To tabulate and visually display the results of individual studies and syntheses, bibliometric indicators of quantity, quality, and structure were applied. These indicators were implemented in an automated manner using Microsoft Excel® in all documents that passed the three exclusion phases (Durieux and Gevenois, 2010).

2.11 Assessment of reporting bias

It is possible that the synthesis is biased due to the lack of results. This may be due to reporting biases that arise from the use of certain synonyms found in thesauri, such as the IEEE. This bias is reflected in the defined inclusion criteria, the search used, and Furthermore, the exclusion of documents whose indexing is incomplete, conference proceedings, and documents of limited relevance as exclusion criteria could result in the omission of valuable information for the construction of knowledge. This is particularly relevant in the context of virtual education in the rural sector.

2.12 Certainly evaluation

The evaluation of certainty in the body of evidence for an outcome is carried out in a general way, in contrast to primary studies that evaluate certainty individually. This is achieved through the independent application of inclusion and exclusion criteria, as well as the definition of bibliometric indicators that allow for the evaluation of the certainty of the evidence. Similarly, the quality and relevance of the documents included in the analysis are evaluated, as are any potential biases defined in the methodological design of the study. Limitations in the discussion phase are also highlighted, which contributes to a more complete and transparent evaluation of the reliability of the results obtained (Figure 1).

Initially, articles were identified through a specific search strategy in each selected information source. Duplicate records were then eliminated to ensure data integrity. The three previously established exclusion phases were implemented to filter the records according to the defined criteria. After this process, a final selection of 194 articles was obtained, which were included in this bibliometric study. This final selection represents a complete and relevant set of literature on the topic of study.

3 Results

The results section presents the emerging trends and patterns in literature through a systematic analysis of the collected data. It provides a detailed overview of the current research landscape in this field, including the exponential growth in article production, the identification of themes, and the emergence of more relevant research approaches. This section offers a comprehensive understanding of the dynamics and evolution of virtual education in rural settings.

A notable increase in the number of articles on the topic is evident, as illustrated in Figure 2, where a 97.8% growth is observed. The years with the highest number of publications are 2022, 2021, and 2023, which suggests a growing interest in this area of study. This is likely motivated by the need to address the challenges and opportunities associated with distance teaching in geographically dispersed contexts and with access limitations to traditional educational resources.

The analysis of the main authors reveals the presence of two distinct groups. On the one hand, an author is identified in yellow, exhibiting high productivity and impact. This individual, Wang J, is a prominent leader in the field. On the other hand, another group is observed, comprising authors in blue. Despite having relatively low productivity, these authors have a notable impact on scientific literature. This group includes authors such as Ramos-Morcillo AJ, Moral-García JE, Leal-Costa C, Ruzafa-Martinez, Tigelaar DEH, and Admiraal W (Figure 3).

Upon examination of the principal periodicals, it becomes evident that three distinct clusters can be discerned. Firstly, those in yellow are those magazines that stand out for both their high productivity and their impact. Among these, Computers and Education and Telemedicine and E stand out. The second group comprises journals in blue, which have a notable impact on scientific literature despite having relatively low productivity. These include the International Journal of Environmental Research and Public Health and Computers in Human Behavior. The third group is observed in green and is mainly distinguished by its high scientific productivity, as is the case of Sustainability. However, this is not necessarily reflected in the number of citations (Figure 4).

With regard to the countries, three distinct groups were identified. The first comprises those nations that stand out for their high productivity and impact on scientific literature, including the United States and India, which are represented by yellow. The second group, in blue, comprises countries whose impact on research is significant despite having relatively low productivity. Among these are Spain and the Netherlands. Finally, a third group of countries is observed in green, which primarily stands out for its high scientific
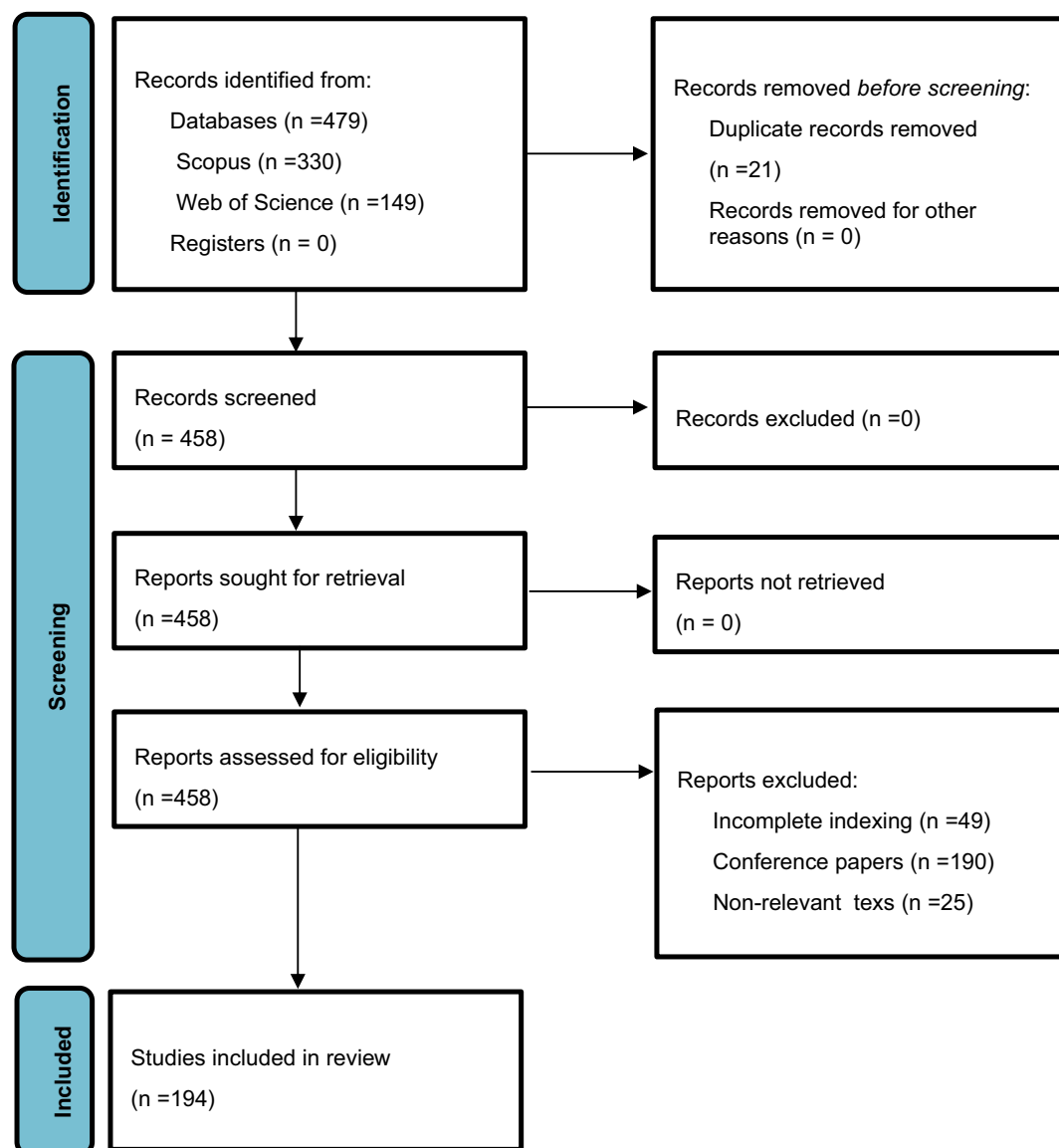
FIGURE 1
PRISMA flowchart. Own elaboration based on Scopus and Web of Science.
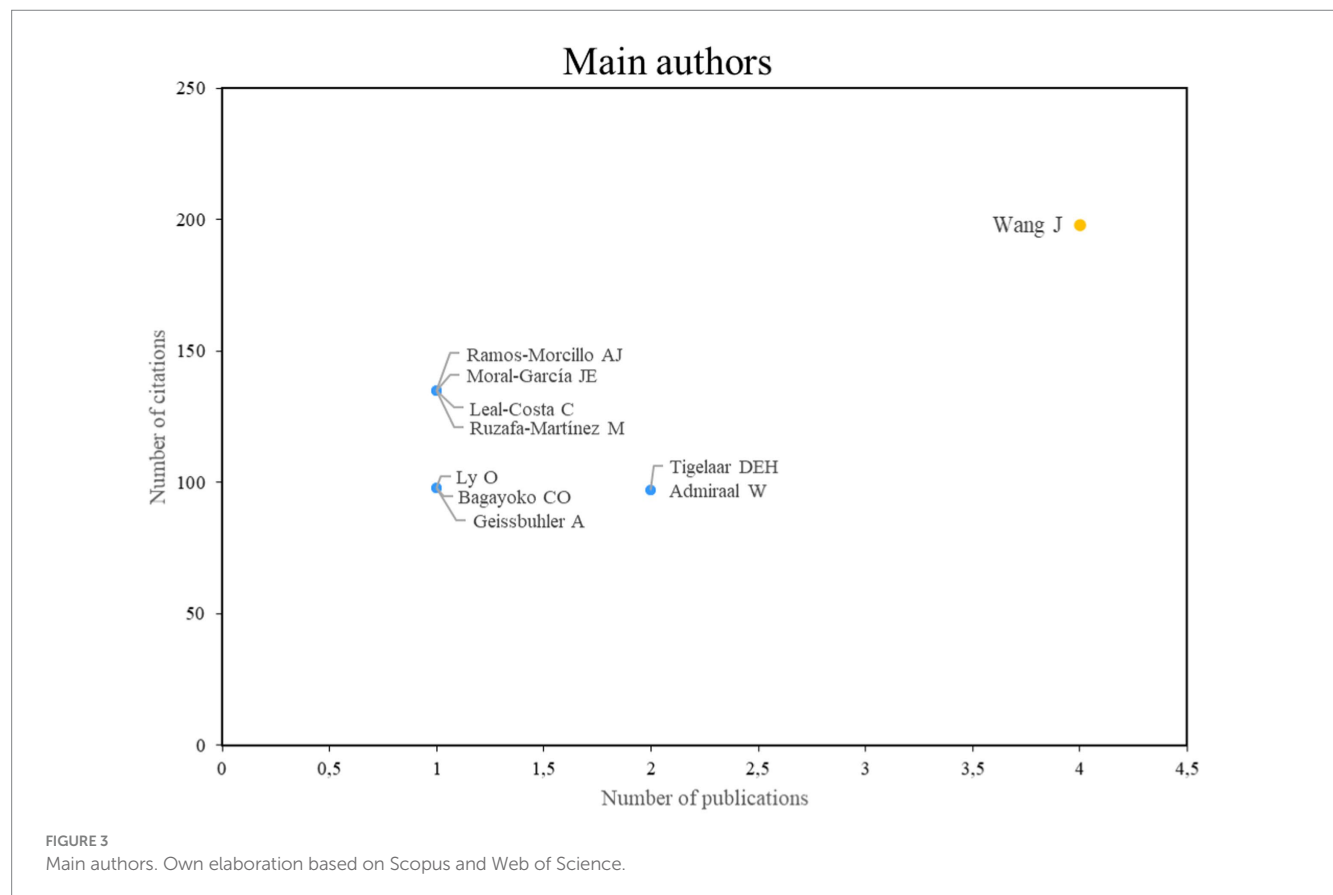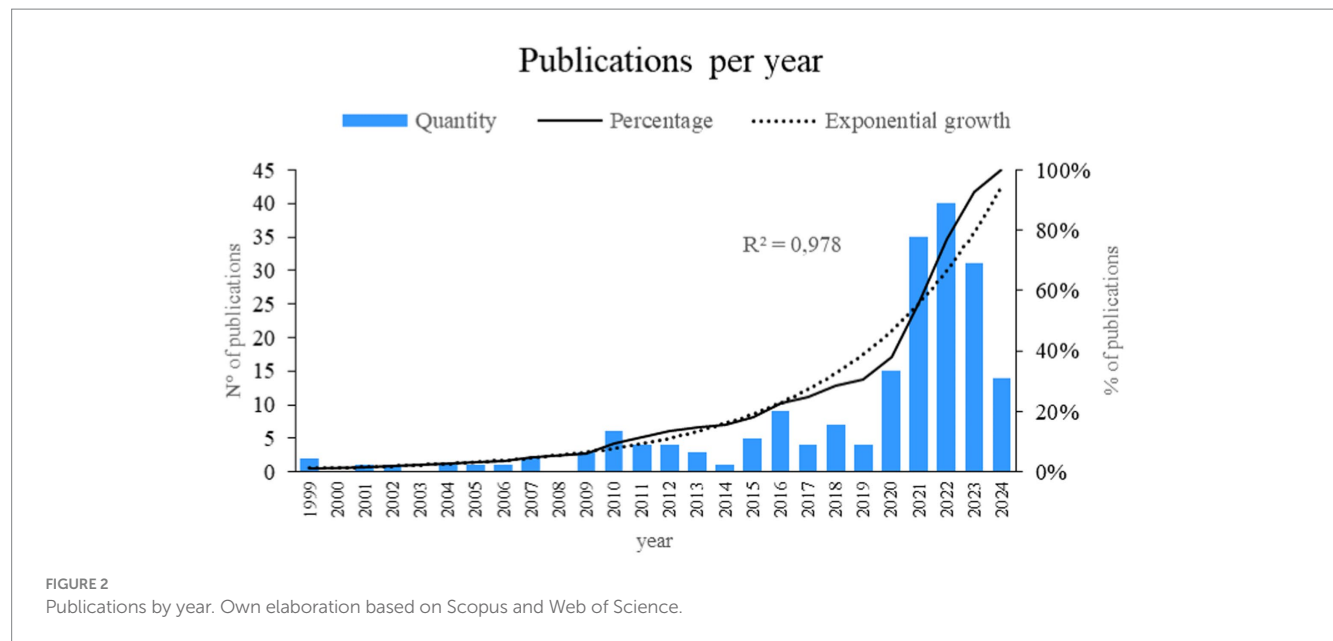
productivity, as is the case of China. However, this does not necessarily correspond to the number of citations (Figure 5).

The present research, as illustrated in Figure 6, examines the thematic evolution in the literature on virtual education in the rural sector. The most frequently used keywords in each year of research from 1999 to 2024 are considered. It is evident that in the year 1999, as a starting point, concepts such as "Transportation" emerged. Over the following years, an evolution was observed in the predominant themes, with a change toward more contemporary themes such as "Professional learning," "Mental Health," "Public Health," and "Online Learning." These reflect current research trends in this field.

The primary network of keyword co-occurrence is exhibited through a total of eight thematic clusters, as illustrated in Figure 7. The purple cluster stands out as the most prominent, composed of terms such as e-learning, technology information and communication (ICT), and teacher training. It is followed by the red cluster, which includes terms such as the Internet of Things, agriculture, active learning, developing countries, and digital literacy. Additionally, other clusters of green, blue, and yellow colors are identified. The orange and purple clusters represent different elements of conceptual affinity within the literature on virtual education in the rural sector.

Figure 8 is included, which is a Cartesian plane figure that measures the frequency of use of keywords on the decreasing concepts. In this case, no keywords are recorded. The third contains the concepts that are not fully consolidated in the field. In quadrant 2, infrequent but highly current words are displayed. Emerging concepts, such as rural health, teachers, digital inclusion, higher education, ICT, and blended learning, are displayed. Concepts that have become consolidated and are growing, such as education, are positioned in quadrant 1, which suggests that these concepts will continue to be relevant and important in the future.

FIGURE 2
Publications by year. Own elaboration based on Scopus and Web of Science.

FIGURE 3
Main authors. Own elaboration based on Scopus and Web of Science.

4 Discussion

The objective of the discussion section is to provide a comprehensive analysis of the findings from research on virtual education in the rural sector. This section examines the practical implications of the findings, identifying how they can be applied to improve education in rural areas.

The authors acknowledge the limitations of the study and provide a critical analysis of the potential influences on the results. A classification of keywords according to their function is also provided, with the most relevant ones for future research highlighted. The primary research gaps are delineated, indicating the areas that necessitate further investigation and analysis.
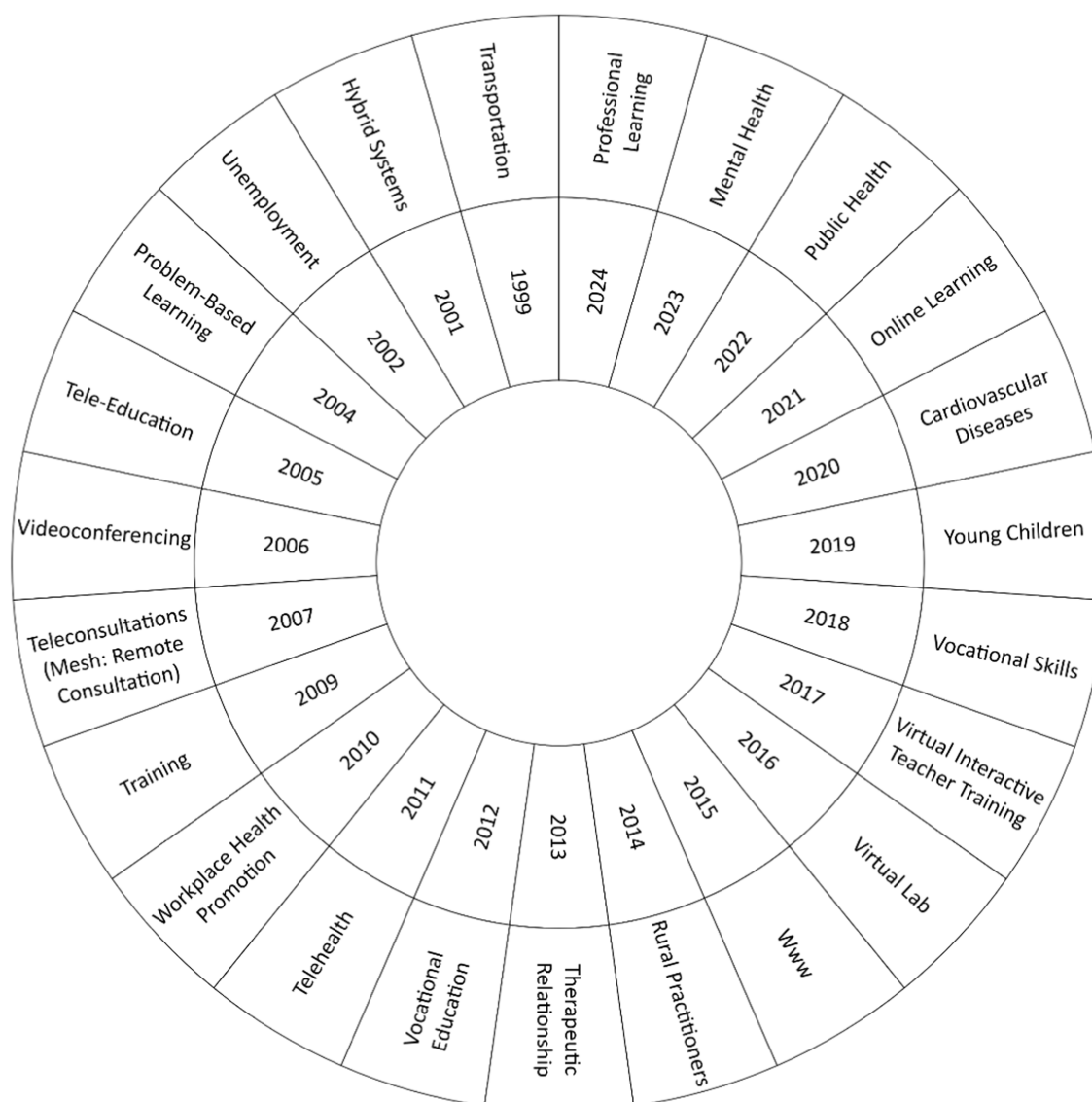
FIGURE 4
Main journals. Own elaboration based on Scopus and Web of Science.

FIGURE 5
Main countries. Own elaboration based on Scopus and Web of Science.
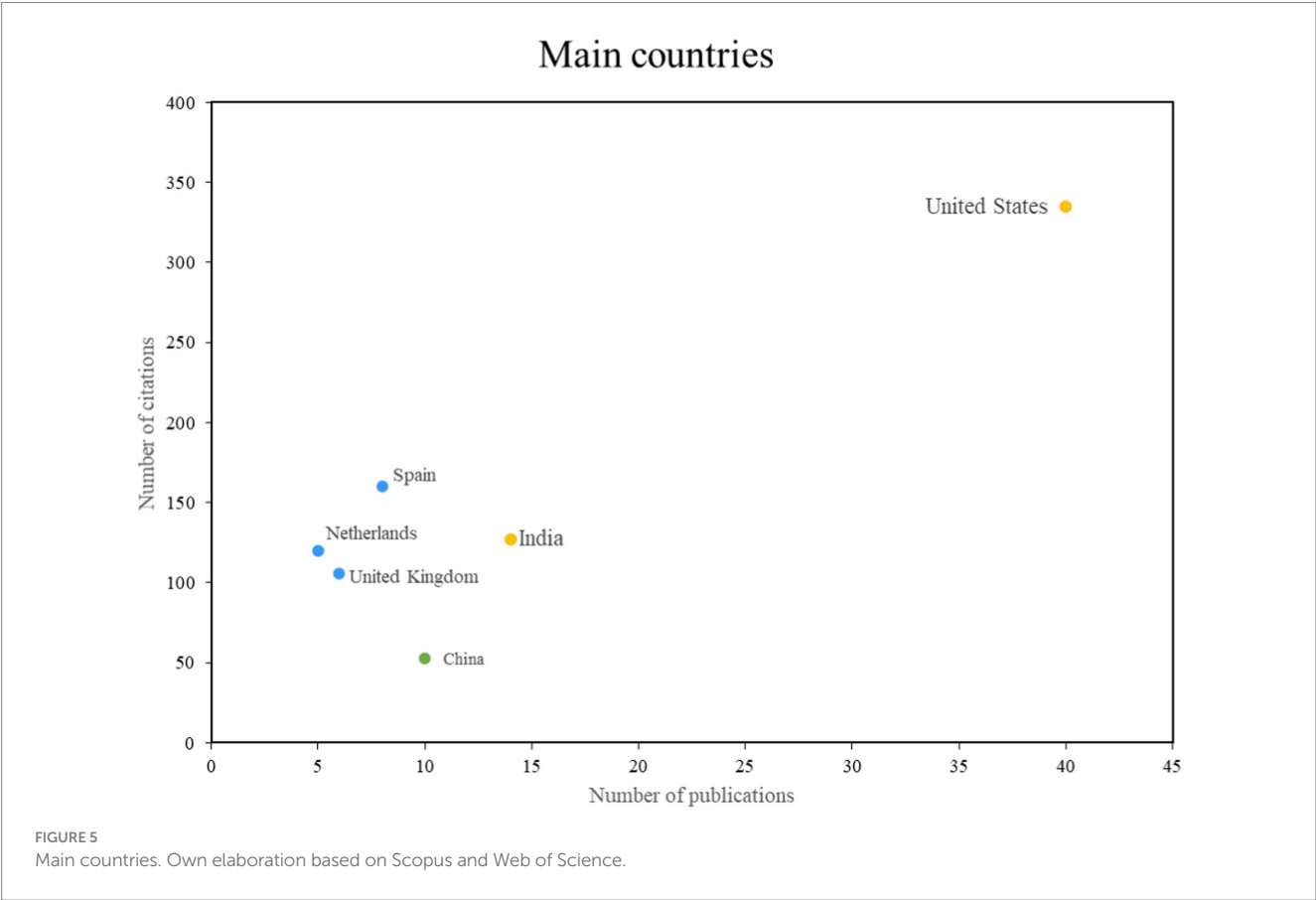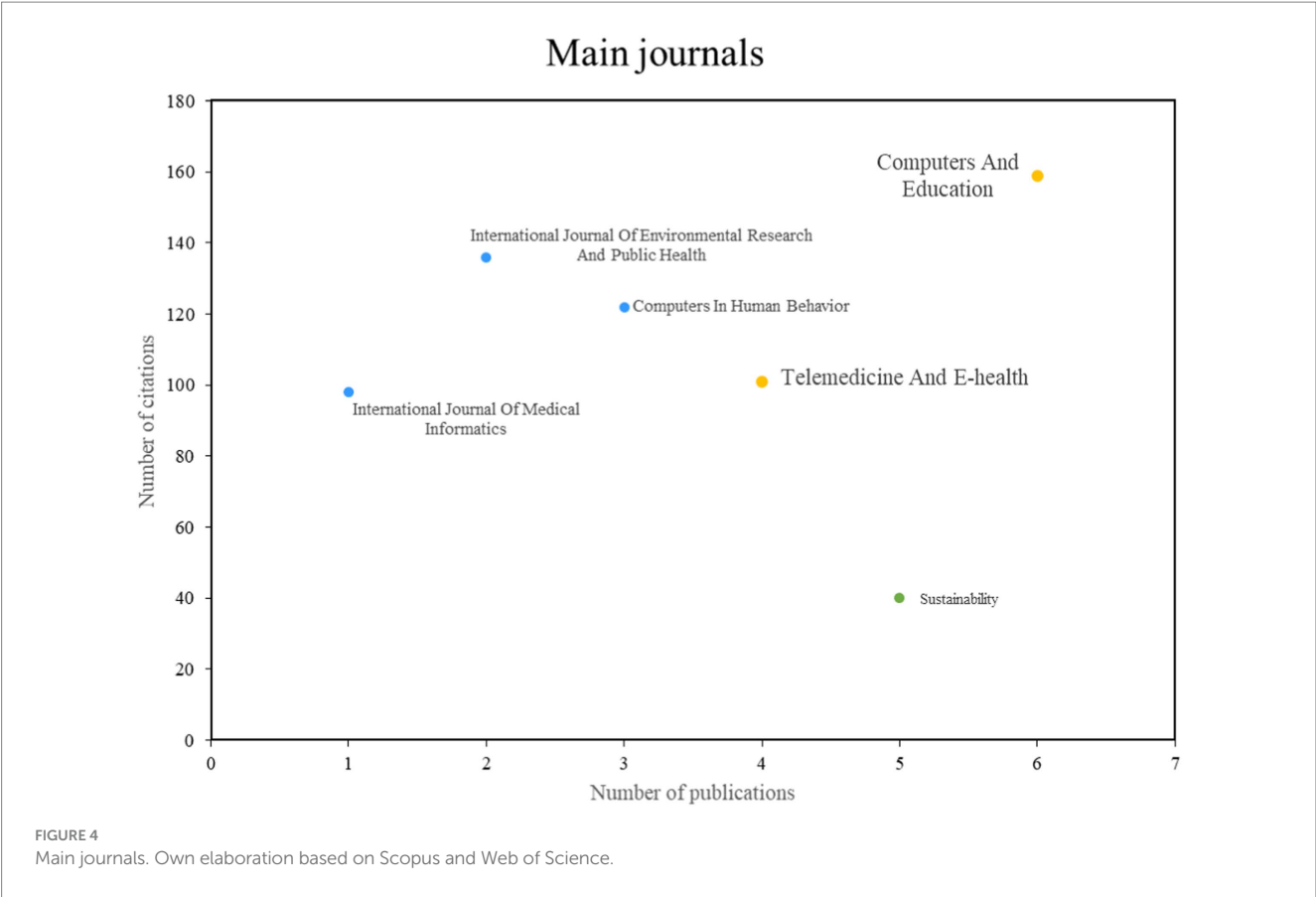
FIGURE 6
Thematic evolution. Own elaboration based on Scopus and Web of Science.
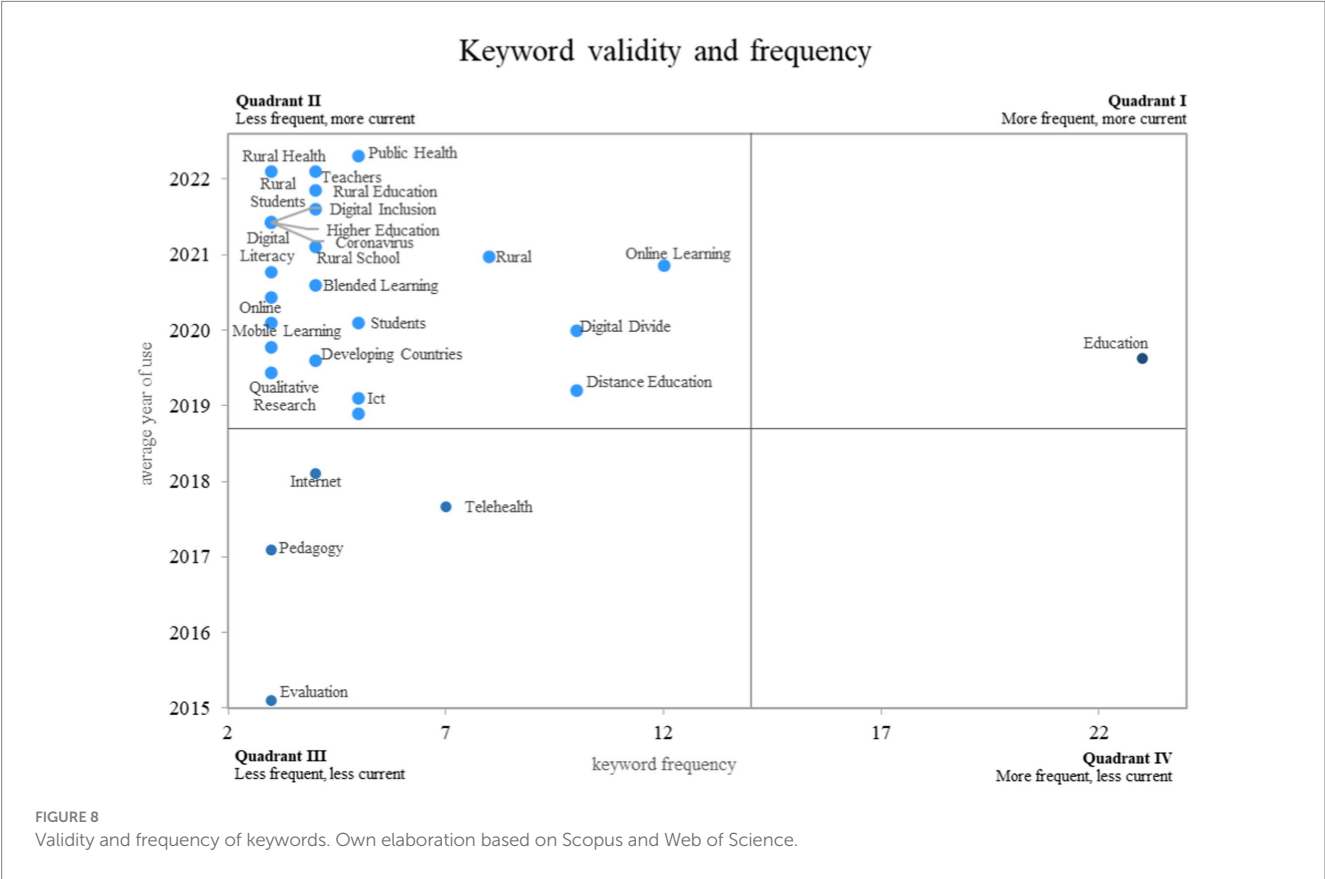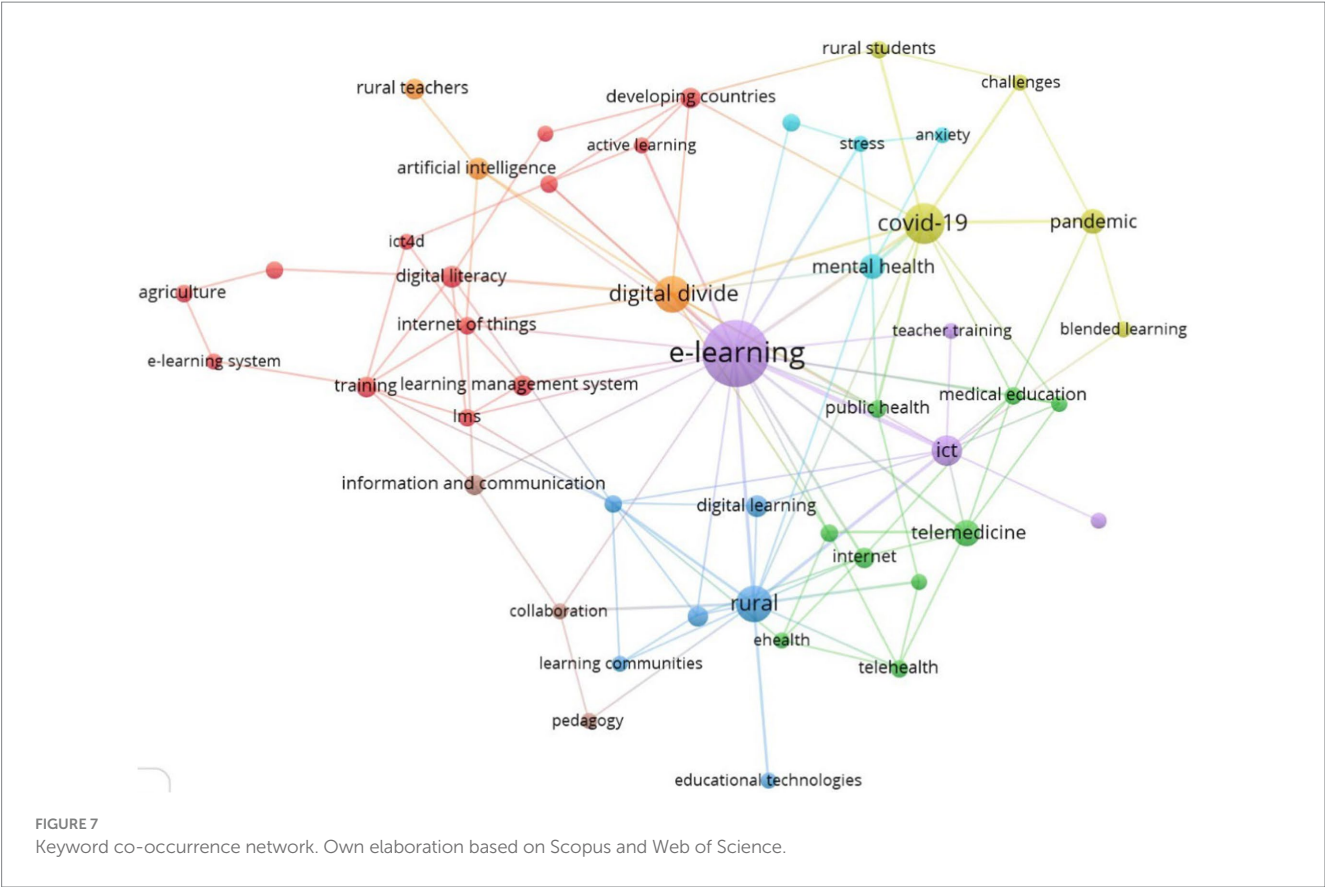
4.1 Analysis of the growth of scientific literature on virtual education in the rural sector

A review of scientific literature on virtual education in rural areas reveals a notable increase in the number of publications in 2022, 2021, and 2023. This growth reflects a growing interest and development in this field. In 2021, the sharing of digital educational resources by rural teachers was investigated, with the transition from motivation to effective sharing behavior being highlighted. The study revealed the importance of communities of practice and digital platforms in improving access and equity in education in rural areas, addressing specific challenges such as the lack of resources and the need for continuous training for teachers (Wang et al., 2021).

In 2022, a study was conducted to investigate students' perceptions of online learning in the context of the ongoing COVID-19 pandemic. The study covered educational levels from high school to university in

remote areas and revealed both the advantages and limitations of learning online. Among the advantages were flexibility and accessibility in the face of connectivity issues and a lack of face-to-face interaction. In addition, the study examined how virtual professional development can promote creator-centered instruction for teachers K-12 (i.e., those who teach at educational levels ranging from kindergarten (K) to twelfth grade (Kiconco et al., 2020), that is, from the beginning of primary education to the end of secondary education). In the United States and other countries, the term is commonly used to refer to the entire range of basic and secondary education. In low-income rural areas, this highlights the importance of professional development interventions to empower teachers and improve pedagogical practices in rural settings (Chen and Cao, 2022).

The year 2023 continued to see a focus on research into the impact of advanced technologies in rural education. During this period, the use of virtual reality was explored as a means of assisting in the education of children on social competencies and social support for

FIGURE 7
Keyword co-occurrence network. Own elaboration based on Scopus and Web of Science.

FIGURE 8
Validity and frequency of keywords. Own elaboration based on Scopus and Web of Science.

those from underrepresented backgrounds. The study provides significant evidence that virtual reality can be a powerful tool for overcoming social and educational barriers, providing a safe and controlled environment for the development of crucial social skills (Wang et al., 2023).

4.2 Analysis of research references on virtual education in the rural sector

In the results section, it was found that Wang J. was the most prominent author in terms of productivity and impact. Conversely, Ramos-Morcillo AJ, together with Moral-García JE, Leal-Costa C, Ruzafa-Martínez M, and Tigelaar DEH and Admiraal W, stood out for their impact. The study analyzed the response of the Chinese rural education system during the COVID-19 crisis, assessing student satisfaction and social and cognitive presence in a remote teaching context. The findings provided valuable insight into how rural schools can adapt quickly to emergency situations and maintain educational quality despite technological limitations. Moreover, the study investigated the associations between feelings and behaviors during the pandemic lockdown and post-lockdown depression/anxiety in Chinese children and adolescents, underscoring the importance of supporting mental health in educational contexts during global crises (Liu et al., 2021).

In a similar vein, Ramos-Morcillo et al. (2020) explored the experiences of nursing students in Spain during the forced transition from in-person to virtual education. Their study highlighted the challenges and adaptations students faced, providing a solid foundation for the development of more resilient and adaptive educational strategies in emergency situations. The research emphasizes the need for a flexible and supportive approach in virtual education to ensure the continuity and quality of learning in times of crisis.

Similarly, Tigelaar and Admiraal, in collaboration with Wang, have made a significant contribution to the field with their study on the use of digital educational resources by rural teachers. This study investigated how rural teachers use these resources to connect their schools with an education of quality, highlighting the motivations and behaviors associated with the integration of technology. In challenging educational environments, the research underscores the significance of access to digital resources and ongoing training for teachers in rural areas, offering a more nuanced understanding of the development of educational policies and pedagogical practices that aim to narrow the educational disparities between urban and rural areas (Wang et al., 2019).

In the field of virtual education in the rural sector, the journals Computers and Education and Telemedicine and E-health have proven to be highly productive and of great impact. Computers and Education has been instrumental in exploring how technology can close the knowledge gap between urban and rural areas. For instance, the efficacy of information technology in narrowing this disparity was explored, furnishing evidence that digital tools can democratize access to knowledge and enhance educational equity. This journal has been pivotal in disseminating research that underscores the significance of technology in education, highlighting innovative practices and their long-term impacts (Chen and Liu, 2013).

"Telemedicine and E-health" has also made a significant contribution to the knowledge base regarding education and health in rural contexts. The examination of the current state and future of telemedicine in India revealed how information technologies can improve access to services for doctors in remote areas. The lessons learned from telemedicine are fundamental to understanding how virtual education can be effectively integrated into health education, particularly in non-formal contexts. Video conferencing with doctors not only provides remote medical care but also serves as a powerful educational tool. Through these interactions, patients and the broader community can receive direct, personalized, evidence-based health education. This allows students to not only receive medical care but also to learn about diagnoses, treatments, and prevention of diseases, thus enriching their formal education (Mishra et al., 2009).

The "International Journal of Environmental Research and Public Health" has had a notable impact, especially in studies on educational response to health emergencies. The results of these studies reveal how public health emergencies affect education and propose strategies to improve educational resilience in times of crisis. Through this study and other similar ones presented in the magazine, significant progress has been made in understanding the challenges and opportunities that education faces during health emergency situations (Ramos-Morcillo et al., 2020).

"Computers in Human Behavior" has distinguished itself by focusing on the study of human behavior and interaction with digital technologies. The journal has investigated the effects of an online instant response system on students in a rural school, revealing how interactive technologies can improve engagement and academic performance in rural contexts. Additionally, the journal provides a platform for studies that analyze the psychological and social implications of the use of technologies in education (Lee et al., 2019).

Finally, the concept of sustainability has been employed to examine the accessibility of online education and the digital divide. This has involved investigating how family conditions and other factors influence the accessibility of online education. The persistent digital divide and its implications for educational sustainability have also been explored. This magazine has highlighted the importance of considering socioeconomic and contextual factors in the design and implementation of virtual education programs. This has contributed to the development of sustainable and equitable solutions (Gu, 2021).

The United States and India have been particularly noteworthy for their high levels of productivity and impact. The United States has demonstrated the effectiveness of health education administered by telemedicine in numerous studies, particularly in the management of chronic diseases such as diabetes. One study highlights the potential of telemedicine, demonstrating how videoconferencing and other technologies can serve not only for remote medical care, but also as powerful educational tools, providing personalized and Evidence-based health education can be provided to patients and communities through these tools, overcoming limitations of geographic areas and improving the health outcomes of communities. The American contribution in this area highlights the importance of integrating technology into education to address challenges specific to rural regions (Kearns et al., 2012).

India has also made significant contributions by implementing virtual laboratories in rural education. The implementation and analysis of remote laboratories in villages in southern India have been shown to complement traditional education, offering access to

advanced learning resources. Furthermore, they have facilitated quality education in remote areas, enabling rural students to participate in hands-on educational experiences that would otherwise be inaccessible. These findings highlight the positive impact of virtual technologies on rural education (Diwakar et al., 2016).

Spain and the Netherlands have been exemplary in terms of impact. In Spain, research was conducted on the teaching and learning process in Physical Education during the COVID-19 pandemic. This research illustrated how educational adaptations in emergency situations can inform lasting improvements in pedagogy and educational resilience. The study allowed us to understand how crises can catalyze innovations in education (Sierra-Díaz et al., 2021). In the Netherlands, the "E-Learning Sudan" program, which provided formal education to out-of-school children, was examined. This work demonstrated the ability of e-learning programs to offer educational opportunities to vulnerable populations, and it illustrated the transformative impact of virtual education in rural and disadvantaged contexts (Stubbé et al., 2016).

China has been a notable example of productivity in the field, with studies investigating the relationship between internet use and the mental health of rural adolescents. The longitudinal study offers valuable insights into how time online affects mental well-being, underscoring the need for a balanced and healthy use of technology in rural education. Research in China demonstrates that the integration of technology must be accompanied by strategies that promote the mental health and well-being of students (Ma and Sheng, 2023).

4.3 Analysis of the thematic evolution of virtual education in the rural sector

In the nascent stages of research on virtual education in the rural sector, the concept of "transportation" served as a foundational element in elucidating the distinctive constraints and obstacles confronting these communities. A study on access to educational opportunities in rural areas of Louisiana was highlighted, where transportation limitations that affected access to educational, economic, and global opportunities were explored. This initial focus on transportation pointed to the need to overcome logistical difficulties to ensure that rural residents could access educational resources. Furthermore, the limitations imposed by transportation restrictions not only constrained physical mobility but also restricted access to quality education. This underscores the necessity of developing solutions to virtual educational services that could reach these isolated communities without relying on traditional transportation infrastructure (Smith, 1999).

In the current research landscape, the concept of "Professional Learning" has gained significant relevance. A study on the difficulties of participation in conferences in the Pacific region highlights the importance of addressing professional development needs in rural environments. It also highlights the need to offer continuous learning and professional development opportunities for rural educators, ensuring that they are equipped with the skills and knowledge necessary to meet the specific challenges of their contexts (Page and Mosen, 2024).

Mental health care has also emerged as a crucial topic in research on virtual education in rural settings. This research has examined mental health among rural Latino immigrants during the COVID-19 pandemic, highlighting the importance of addressing emotional well-being needs of rural communities. The integration of psychosocial support into virtual education programs is evident, recognizing the significant impact that mental health has on the learning and academic development of rural students (Goldman-Mellor et al., 2023).

Conversely, research on virtual education has also placed an emphasis on public health. A study on the integration of sex and gender in professional development courses on diabetes and depression, for instance, highlights the importance of addressing aspects of public health relevant to rural communities, such as the prevention and management of chronic diseases, through non-formal programs (Tardif et al., 2022).

The concept of "Online Learning" has been the subject of increasing attention, as evidenced by a study on the implications of the COVID-19 pandemic on the learning satisfaction of university students. The study reveals the need to develop learning frameworks effective remote learning programs that address specific challenges faced by rural students, such as accessibility to technology and participation in virtual learning environments.

4.4 Analysis of the thematic clusters on virtual education in the rural sector

Upon examination of the primary keyword co-occurrence network, a thematic cluster in purple was identified. This cluster is primarily comprised of keywords such as "E-Learning," "ICT" (Information and Communication Technologies), and "Teacher Training," which reflects the significance of integrating technology in rural education and the emphasis on the training and professional development of teachers in the effective use of digital tools in the classroom. Researchers have addressed these issues, identifying strategies to reduce the digital divide and improve the preparation of educators in rural settings (Herdon et al., 2015; Hannaway et al., 2019).

In contrast, another relevant cluster in red is made up of keywords such as "Internet of Things," "Agriculture," "Active Learning," "Developing Countries in Development," and "Digital Literacy." This cluster reflects the growing attention to the application of technology in agriculture and rural development, as well as the importance of promoting digital literacy in rural contexts. Researchers have conducted studies in these areas, emphasizing the significance of the Internet of Things, agricultural digitalization, and strategies to address digital inequalities in rural settings (Pratama and Scarlatos, 2020; Ji et al., 2023; Dhaigude and Ghosh, 2023; Rundel and Salemink, 2021).

4.5 Analysis of the frequency and conceptual validity around virtual education in the rural sector

Upon analysis of the Cartesian plane of the Figure 8, it became evident that several emerging concepts reflected significant trends within the scientific field. These concepts included "Rural Health," "Teachers," and "Digital Inclusion," which are crucial both in the present and in the near future. The concept of "Rural Health" addresses the importance of health in rural settings, where access to healthcare services may be limited. Telemedicine initiatives and interprofessional

collaborations have been explored to improve access to healthcare in rural areas, underscoring the necessity to integrate health into the virtual education agenda. This integration entails learning from telemedicine to bring rurality formal virtual education, thereby addressing the comprehensive needs of rural communities. The connection between health and virtual education underscores the necessity of adapting educational approaches to meet the distinctive requirements of these communities, whether in a formal or informal context. This ensures equitable access to education and health care (Browne et al., 2022).

Conversely, the term "teachers" underscores the pivotal role of educators in the successful implementation of virtual education in rural settings. Studies have examined the experiences and perspectives of teachers during the COVID-19 pandemic, identifying lessons learned and recommended actions to enhance the quality of digital learning. This underscores the necessity to provide educators with the requisite support and training to effectively utilize information and communication technologies in their educational practices (Guzzo et al., 2022).

Finally, the concept of "digital inclusion" refers to the necessity of ensuring that all individuals, regardless of their geographic location or socioeconomic status, have access to and the requisite skills to fully participate in the digital society. The perception of online learning among students in India has been examined during the pandemic, highlighting the importance of addressing digital divides and promoting digital inclusion to ensure equity in virtual education in rural settings (Bast, 2021).

Upon examination of quadrant 1, the keyword "Education" emerges as a prominent, growing, and consolidated concept within the research field. The pervasive presence of this term serves as a salient example of the utilization of online education and telephone consultations to facilitate continuing medical education and medical consultations in Francophone Africa. The study elucidates how virtual education can transcend geographical boundaries and enhance accessibility to education and healthcare in rural areas, underscoring its pivotal role in addressing the educational and health needs of rural communities globally (Geissbuhler et al., 2007).

4.6 Comparison with other studies

This study presents findings that align and contrast with several recent investigations in the field. For instance, while Hamlin et al. (2023) conducted a longitudinal analysis on the effectiveness of virtual schools in rural areas and found that access to education improved, albeit with limitations in academic performance, the present study reinforces this conclusion by showing that, although the number of investigations on the topic has grown exponentially in recent years, challenges persist in terms of digital inclusion and educational quality. Furthermore, Guerrero-Casquete et al. (2023) emphasized how the advent of the pandemic precipitated the swift adoption of virtual education, yet simultaneously exposed critical infrastructure and connectivity deficiencies in rural contexts. This study underscores this point by methodically analyzing emergent trends in the extant literature and underscoring the significance of digital inclusion.

In relation to the training of teachers and the integration of ICTs in the context of rural education, this study concurs with the findings of Gaitán and Pérez (2024) on the necessity to enhance the training of

digital skills. While the research of the aforementioned authors focuses on the preparation of future teachers for teaching in rural settings, the present bibliometric analysis identifies the evolution of interest in these subjects and highlights how concepts such as e-learning, digital inclusion, and teacher training have gained prominence in recent years. However, while Guzzo et al. (2022) posit that a paucity of teacher preparation had a deleterious effect on the quality of digital learning during the pandemic, this study provides evidence to complement this view by showing the growth of research in this field and the consolidation of certain trends, suggesting a greater recognition of the importance of digital training in rural teaching.

Finally, the role of virtual education in the field of rural health, as analyzed by Browne et al. (2022), presents an interesting contrast to their study. While they investigate the impact of telemedicine on the training of health professionals in remote communities, this bibliometric analysis identifies rural health as an emerging concept within virtual education in rural settings. This finding suggests a convergence between the fields of virtual education and rural health, emphasizing the necessity for future interdisciplinary research to explore the intersection of education, technology and health in rural contexts. Consequently, the present study not only validates previous findings but also provides a broader perspective on the evolution of scientific literature in this field, highlighting the growing importance of virtual education as a key tool for educational equity in rural areas.

4.7 Classification of keywords on virtual education in the rural sector according to their function

Table 1 presents a classification of the principal emerging and growing keywords according to their function. This classification enables the identification of the characteristics and applications associated with each of the categorized functions.

Table 1 provides a structured overview of the principal emerging and growing keywords in the field of virtual education in the rural sector, thereby facilitating a more comprehensive understanding of the topics, technologies, and contexts that influence this area of research.

4.8 Theoretical implications

Analysis of publication frequency per year reveals periods of heightened research activity, reflecting evolving research dynamics and shifting focus areas. This chronological overview aids in understanding the topic's evolution and its current relevance.

Identifying principal theoretical references in rural virtual education underscores foundational concepts and methodologies guiding research. This contextualization within a theoretical framework informs future studies and advancements in the field.

Thematic evolution analysis tracks shifting research topics, identifying emerging trends and areas needing further exploration. Co-occurrence of keywords illuminates concept relationships, offering insights into the complexity of the subject.

Identifying emerging keywords and research gaps informs future research directions, guiding efforts toward critical areas needing

TABLE 1 Classification of keywords according to their function.

Keyword	Associated tools	Applications	Characteristics
Rural health	Telemedicine, mHealth	Remote medical consultations, Health monitoring, Health education	Access to healthcare in remote areas
Teachers	LMS (Learning Management System), Videoconference	Teacher training, Online tutoring, Remote assessment	Facilitates the continuous training of teaching staff
Digital inclusion	Internet, Computers, Mobile Devices	Access to online educational resources, Digital communication, Participation in the digital society	Reducing the digital divide in rural communities
Higher education	Online Courses, Virtual Classrooms	Access to higher education, Collaborative research, Professional development	Expands educational opportunities in rural areas
ICT	Internet Connectivity, Digital Devices	Implementation of educational technologies, Data management, Remote communication	Improve connectivity and interaction in educational environments
Blended learning	Online Platforms, Learning Apps	Integration of face-to-face and online methods, Personalization of learning, Flexibility in the schedule	Combine the best of both learning environments
Education	E-learning Platforms, Digital Resources	Access to information, Skills development, Online collaboration	Promotes the acquisition of knowledge and skills in rural environments

Own elaboration based on Scopus and Web of Science.

deeper exploration in rural virtual education. These insights drive progress in knowledge and practice in the field.

4.9 Practical implications

This article offers practical implications for stakeholders including researchers, educators, policymakers, and professionals in the field. It identifies a thematic evolution in research focus from transportation to critical areas such as professional learning, mental health, public health, and online learning. This underscores the need to adapt educational strategies and interventions to address emerging issues crucial in rural communities.

The identification of key thematic clusters such as e-learning, ICT, and teacher training highlights the imperative to enhance digital competencies among rural educators and integrate technology effectively in remote educational settings. This insight can inform the development of responsive teacher training programs and educational resources, promoting equity and quality in virtual education.

Analysis of emerging keywords emphasizes the importance of prioritizing areas like rural health, digital inclusion, higher education, and blended learning in educational policies and programs for rural areas. These findings guide resource allocation and decision-making regarding technological infrastructure, teacher training, and access to health services, aiming to narrow educational gaps and enhance rural quality of life through virtual education.

Identifying emerging thematic areas in virtual education for rural settings facilitates the design of interventions and policies tailored to community needs. Focus on mental and public health supports implementation of psychosocial programs and telemedicine services suited to rural contexts, enhancing overall community well-being.

Furthermore, examining keyword evolution and theoretical references encourages interdisciplinary collaboration and knowledge transfer. This approach promotes innovative solutions addressing the multifaceted challenges in rural education and development.

Practical implications extend to economic and workforce domains, emphasizing the importance of professional learning and digital skill development in rural areas. Implementing training and employment programs prepares rural populations for the digital labor market, reducing skill gaps and fostering economic inclusion.

Lastly, insights from bibliometrics inform policymaking for sustainable development and educational equity. Understanding trends and emerging needs in virtual education for rural contexts aids in designing strategies that ensure equal access to quality education and foster holistic development of rural communities in the knowledge society.

4.10 Limitations

A key limitation of this study is its reliance on Scopus and Web of Science for bibliographic data collection; while these databases are widely recognized in academia, access restrictions, indexing errors, and the limited inclusion of specialized journals on virtual education in rural contexts may result in the omission of relevant publications. Additionally, the selection of keywords and search criteria may introduce biases, potentially limiting the representation of diverse perspectives and approaches.

Another constraint lies in the use of Microsoft Excel® and VOSviewer® for bibliometric analysis, despite the fact that these tools facilitate data processing and visualization. They have inherent limitations in handling large datasets and capturing nuanced qualitative insights. Moreover, the bibliometric approach effectively identifies overarching trends but does not provide an in-depth understanding of the sociocultural and economic factors shaping virtual education in rural areas.

To enhance the comprehensiveness of future research, it would be beneficial to expand the database selection, integrate qualitative methodologies, and incorporate case studies on specific rural contexts. Additionally, exploring the effectiveness of various

virtual education models while considering factors such as infrastructure, teacher training, and technology access could offer a more holistic perspective on the challenges and opportunities in this field.

4.11 Investigative gaps

Table 2 presents the principal research gaps identified in the field of virtual education in the rural sector. These gaps are derived from the bibliometric analysis carried out and reflect aspects that have not been sufficiently explored or represented in existing literature. By identifying these gaps, it is possible to provide guidance for future research that seeks to address critical aspects and advance knowledge about virtual education in rural contexts.

These gaps present potential avenues for future research to contribute to the advancement and enhancement of virtual education

in rural contexts, as well as to inform educational policies and practices directed toward these communities.

4.12 Research agenda

Virtual education has significantly transformed rural education by providing access to previously inaccessible resources and learning opportunities, overcoming geographic and socioeconomic barriers. Future research should evaluate platform effectiveness and identify best practices to maximize educational impact. Further investigation is needed to optimize student interaction and engagement in online learning environments, especially in rural contexts. Research should also focus on developing sustainable technological infrastructures to ensure equitable access to online education.

Also, the virtual education offers opportunities for educational inclusion in rural areas, addressing specific needs and cultural

TABLE 2 Research gaps.

Category	Investigative gaps	Justification	Questions for future researchers
(1) Thematic gaps	1. Adaptation of the virtual education curriculum in a rural context	It is imperative that the curriculum for virtual education be both relevant and contextualized in order to meet the specific needs of students in rural areas. Such adjustments may entail alterations to the content, methodology, and educational resources employed.	How can virtual education curricula be adapted to address the unique educational and cultural needs of students in rural areas? What teaching and learning strategies could be most effective in rural virtual education contexts?
	2. Impact of connectivity and digital infrastructure on the quality of virtual education in rural environments.	Despite the expansion of virtual education, challenges related to the accessibility and quality of access to technology in rural areas persist.	How does the availability and quality of connectivity affect the learning experience in rural areas? What strategies can improve digital infrastructure in these regions?
	3. Evaluation of the impact of virtual education on the well-being and socio-emotional development of rural students.	It is essential to comprehend the impact of virtual education on not only academic, but also socio-emotional aspects, in rural communities.	What are the long-term effects of virtual education on the mental health and well-being of rural students? What interventions can improve socioemotional adaptation in virtual rural learning environments?
(2) Geographic gaps	1. Specific research on the implementation of virtual education in rural regions of developing countries.	The differing infrastructure, access to technology, and sociocultural contexts between developed and developing countries may necessitate the implementation of disparate approaches and solutions.	What are the unique challenges that rural communities in developing countries face when adopting virtual education? What strategies may be most effective in contexts with limited resources?
	2. Differentiation in the design of virtual learning environments between rural and urban areas	The needs and characteristics of students in rural areas may differ significantly from those of urban students. Consequently, it is of paramount importance to design virtual learning environments that are tailored to the specific characteristics of each context, in order to guarantee an effective educational experience.	What are the main differences in the needs and preferences of students in virtual learning environments between rural and urban areas?
	3. Comparative studies between rural and urban areas to identify differences in the effectiveness and accessibility of virtual education.	An understanding of the disparities between rural and urban areas can inform the formulation of policies and practices that address the specific needs of each context.	How can virtual learning environments be designed that are inclusive and accessible for students in rural areas?

(Continued)

TABLE 2 (Continued)

Category	Investigative gaps	Justification	Questions for future researchers
(3) Interdisciplinary gaps	1. Integration of knowledge from education, technology, public health and community development to address the complexities of virtual education in rural areas.	To develop effective solutions to improve virtual education in rural contexts, it is necessary to adopt an interdisciplinary approach that considers multiple dimensions and perspectives.	How can researchers and practitioners from different disciplines collaborate to design and implement effective virtual education programs in rural areas? What strategies can promote interdisciplinary collaboration in this field?
	2. Measurement of digital skills of students and teachers to face virtual education	It is evident that digital skills are of paramount importance for success in virtual education environments. Nevertheless, the assessment and improvement of these competencies may vary depending on the context, particularly in rural areas where there may be disparities in access to technology and training.	What are the most important digital competencies for students and teachers in virtual education environments in rural areas? How can these competencies be measured effectively and accurately?
	3. Studies that analyze the interaction between sociocultural and technological factors in the implementation of virtual education in rural contexts.	An understanding of social and cultural dynamics can assist in the adaptation of virtual educational interventions to ensure cultural sensitivity and contextual relevance.	How do cultural and social norms influence the acceptance and effectiveness of virtual education in rural areas? How can educational technologies be designed considering the cultural particularities of each rural community?
(4) Temporal gaps	1. Longitudinal research on the long-term effects of virtual education on the academic performance and employability of rural students.	It is crucial to comprehend how the educational and employment outcomes of rural students evolve as they progress in their education and integrate into the labor market.	What are the long-term trends in the academic performance and career paths of rural students who have participated in virtual education programs? How do temporal factors influence the long-term success of virtual education in rural contexts?
	2. Identification of triggering factors of student dropout in virtual education in a rural context	Student attrition represents a significant challenge in virtual education, particularly in rural areas where additional obstacles may exist. Identifying factors that contribute to school dropout is of paramount importance for the development of effective student retention strategies.	What are the main factors contributing to student dropout in virtual education environments in rural areas? How do these factors vary compared to urban environments?

Own elaboration based on Scopus and Web of Science.

contexts of communities. Research could explore the long-term socioeconomic impact of these programs and their contribution to community growth. Telemedicine plays a crucial role in rural health education, enhancing access to medical training and resources. Future research should examine the integration of telemedicine with virtual education initiatives, assessing their effectiveness in improving community health and healthcare education.

Blended Learning combines in-person and virtual education, offering flexibility in areas with limited educational infrastructure. Research should identify effective strategies for its implementation in rural contexts and evaluate its impact on academic performance and skill development. Virtual education provides rural students with opportunities for quality education without extensive travel. Future research could focus on creating targeted educational programs and assessing the psychological and social impacts of virtual learning on rural students.

Bridging the digital divide is crucial for equitable access to virtual education in rural areas. Research should investigate funding models and policies to develop technological infrastructure and assess the impact of reduced digital disparities on academic and economic development. Virtual education enhances public health education in rural areas by disseminating crucial health information and training programs. Future research should explore integrating virtual education into public health initiatives and strengthening collaboration between educational and health institutions.

ICT are integral to effective virtual education in rural areas, facilitating access to resources and digital skills. Research should explore innovative ICT integration models and effective training approaches for teachers and students in rural settings. Virtual education has the potential to mitigate educational disparities in developing countries by providing access to global resources. Future research should focus on adapting and scaling virtual education
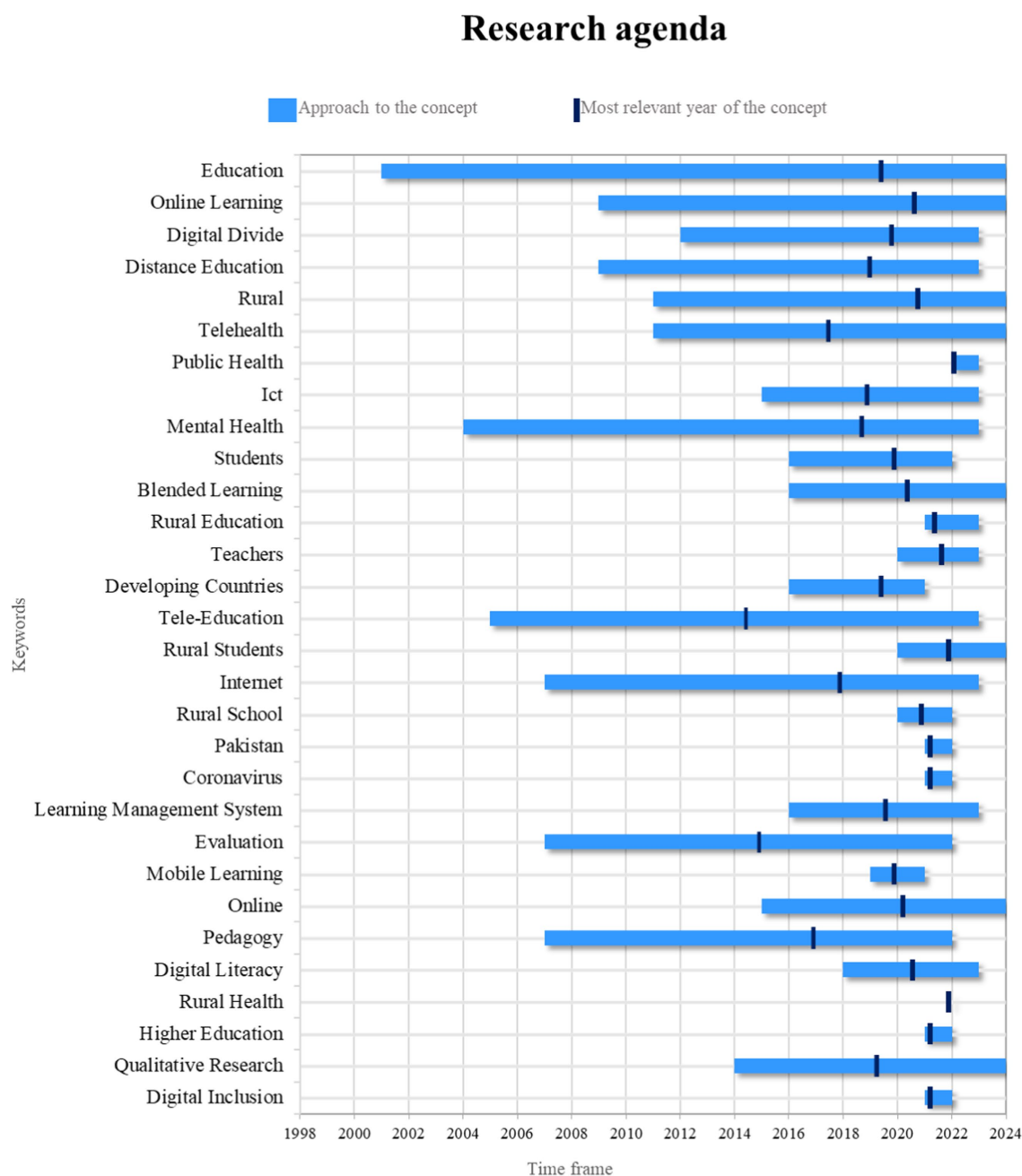
FIGURE 9
Research agenda. Own elaboration based on Scopus and Web of Science.

programs and assessing their long-term impact on economic and social development (Figure 9).

5 Conclusion

Firstly, an analysis of scientific production reveals that the years with the greatest interest in virtual education in the rural sector have been 2022, 2021, and 2023. This increase coincides with the global impact of the COVID-19 pandemic, which promoted the rapid adoption and adaptation of educational technologies in rural contexts to ensure continuity of learning.

The growth of literature on virtual education in the rural sector has been exponential, reflecting a sustained increase in research and publication of scientific articles. This growth in literature on virtual education in rural areas suggests a growing recognition of the importance of this educational tool as a means of overcoming barriers to learning.

The most significant research contributions in this field include those of Wang J, whose work has been instrumental in advancing the body of knowledge on this topic. The most influential journals, such as "Computers and Education" and "Telemedicine and E-health," and countries such as the United States and India, also stand out for their prolific production and the significant impact of their studies,

positioning themselves as leaders in research on virtual education in rural contexts.

The thematic evolution of scientific production has demonstrated a transition from an initial focus on "Transportation" topics to more contemporary approaches, including "Professional Learning" and "Mental Health." Thematic cluster analysis revealed that "e-learning," "ICT," and "teacher training" constitute the conceptual core of the current literature, demonstrating high conceptual affinity and highlighting crucial areas for the development and effective implementation of virtual education in rural settings.

In the field of rural virtual education, the terms "rural health," "teachers," "digital inclusion," and "higher education" are emerging as key concepts. These concepts reflect emerging trends and areas of growing interest that could serve as a guide for the agenda. Future research into these topics will allow the development of more effective and equitable strategies for education in rural areas, consolidating existing knowledge and addressing the new realities and challenges of the 21st century.

Regarding the themes that are positioned as protagonists for the design of a research agenda on virtual education in the rural sector, it was found that a deeper understanding of the concepts of "Education," "Rural Health," "Teachers," "Digital Inclusion," and "Higher Education" is crucial for future studies. These emerging and consolidated themes should guide future research. A more comprehensive understanding and more effective application of virtual education in rural contexts can be achieved in the future by focusing on technological barriers, improving teacher training, and promoting digital inclusion. This will ensure that virtual education is accessible and beneficial for all rural communities.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

References

Bast, F. (2021). Perception of online learning among students from India set against the pandemic. *Front. Educ.* 6:705013. doi: 10.3389/feduc.2021.705013

Browne, T., McKinney, S. H., Duck, L., Baliko, B., Blake, E. W., and Bethel, S. R. (2022). An academic-community interprofessional telehealth online training partnership: impact on students and providers. *J. Interprof. Care* 36, 643–650. doi: 10.1080/13561820.2021.1967896

Castilla, D., Botella, C., Miralles, I., Bretón-López, J., Dragomir-Davis, A. M., Zaragoza, I., et al. (2018). Teaching digital literacy skills to the elderly using a social network with linear navigation: a case study in a rural area. *Int. J. Hum. Comput. Stud.* 118, 24–37. doi: 10.1016/j.ijhcs.2018.05.009

Chen, Y., and Cao, L. (2022). Promoting maker-centred instruction through virtual professional development activities for K-12 teachers in low-income rural areas. *Br. J. Educ. Technol.* 53, 1025–1048. doi: 10.1111/bjet.13183

Chen, R. S., and Liu, I. F. (2013). Research on the effectiveness of information technology in reducing the rural–urban knowledge divide. *Comput. Educ.* 63, 437–445. doi: 10.1016/j.compedu.2013.01.002

Criollo-C, S., Guerrero-Arias, A., Jaramillo-Alcázar, Á., and Luján-Mora, S. (2021). Mobile learning technologies for education: benefits and pending issues. *Appl. Sci.* 11:4111. doi: 10.3390/app11094111

Dhaigude, A. S., and Ghosh, R. (2023). AgriMitr: digitalizing the agricultural landscape with satellite imaging. *Commun. Assoc. Inf. Syst.* 52, 1119–1124. doi: 10.17705/1CAIS.05251

Diwakar, S., Kumar, D., Radhamani, R., Sasidharakurup, H., Nizar, N., Achuthan, K., et al. (2016). Complementing education via virtual labs: implementation and deployment of remote laboratories and usage analysis in south Indian villages. *Int. J. Online Eng.* 12, 8–15. doi: 10.3991/ijoe.v12i03.5391

Durieux, V., and Gevenois, P. A. (2010). Bibliometric indicators: quality measurements of scientific publication. *Radiology* 255, 342–351. doi: 10.1148/radiol.09090626

Gaitán, S. J. G., and Pérez, A. C. G. (2024). Competencias TIC en educación virtual en contextos rurales: un estudio descriptivo en estudiantes del profesorado de Enseñanza Media en Pedagogía y Ciencias Sociales de la Universidad Panamericana. *MLS Educ. Res.* 8, 358–374. doi: 10.29314/mlser.v8i2.2178

Geissbuhler, A., Bagayoko, C. O., and Ly, O. (2007). The RAFT network: 5 years of distance continuing medical education and tele-consultations over the internet in French-speaking Africa. *Int. J. Med. Inform.* 76, 351–356. doi: 10.1016/j.ijmedinf.2007.01.012

Goldman-Mellor, S., Plancarte, V., Perez-Lua, F., Payán, D. D., and Young, M. E. D. T. (2023). Mental health among rural Latino immigrants during the COVID-19 pandemic. *SSM Mental Health* 3:100177. doi: 10.1016/j.ssmmh.2022.100177

Gu, J. (2021). Family conditions and the accessibility of online education: the digital divide and mediating factors. *Sustain. For.* 13:8590. doi: 10.3390/su13158590

Guerrero-Casquete, E. M., Chiliquinga-Campos, E. V., Velasco-Almachi, L. D., and Pimbo-Tibán, A. G. (2023). La educación en el sector rural en tiempos de pandemia por la COVID-19. *Revista Científica UISRAEL* 10, 143–154. doi: 10.35290/rcui.v10n2.2023.757

Guzmán Rincón, A., Barragán, S., and Cala, V. F. (2021). Rurality and dropout in virtual higher education programmes in Colombia. *Sustain. For.* 13:4953. doi: 10.3390/su13094953

Guzzo, T., Boffo, S., Ferri, F., Gagliardi, F., and Grifoni, P. (2022). Towards quality digital learning: lessons learned during COVID-19 and recommended actions—the teachers' perspective. *Sustain. For.* 14:8438. doi: 10.3390/su14148438

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Hamlin, D., Adigun, O., and Adams, C. (2023). Do virtual schools deliver in rural areas? A longitudinal analysis of academic outcomes. *Comput. Educ.* 199:104789. doi: 10.1016/j.compedu.2023.104789

Hannaway, D., Govender, P., Marais, P., and Meier, C. (2019). Growing early childhood education teachers in rural areas. *Africa Educ. Rev.* 16, 36–53. doi: 10.1080/18146627.2018.1445974

Harefa, S., and Sihombing, G. L. A. (2022). Students' perception of online learning amidst the COVID-19 pandemic: A study of junior, senior high school and college students in a remote area. *F1000Res* 10, 1–15. doi: 10.12688/f1000research.52152.2

Herdon, M., Botos, S., and Várallyai, L. (2015). Decreasing the digital divide by increasing e-innovation and e-readiness abilities in agriculture and rural areas. *Int. J. Agric. Environ. Inform. Syst.* 6, 1–18. doi: 10.4018/ijaeis.2015010101

Ji, J., Huang, A., Liu, C., and Dai, L. (2023). The application of the SOFM neural network and internet of things in rural revitalization. *IEEE Access* 11, 119427–119435. doi: 10.1109/ACCESS.2023.3327131

Kadirbergenovna, B. L. (2022). Massive open online course basic requirements for digital educational resources, 187–190.

Kearns, J. W., Bowerman, D., Kemmis, K., Izquierdo, R. E., Wade, M., and Weinstock, R. S. (2012). Group diabetes education administered through telemedicine: tools used and lessons learned. *Telemed. e-Health* 18, 347–353. doi: 10.1089/tmj.2011.0165

Kiconco, R. I., Rooks, G., and Snijders, C. (2020). Learning mobile money in social networks: comparing a rural and urban region in Uganda. *Comput. Human Behav.* 103, 214–225. doi: 10.1016/j.chb.2019.09.005

Kulal, A., Dinesh, S., Abhishek, N., and Anchan, A. (2024). Digital access and learning outcomes: a study of equity and inclusivity in distance education. *Int. J. Educ. Manag.* 38, 1391–1423. doi: 10.1108/IJEM-03-2024-0166

Lee, C. C., Hao, Y., Lee, K. S., Sim, S. C., and Huang, C. C. (2019). Investigation of the effects of an online instant response system on students in a middle school of a rural area. *Comput. Human Behav.* 95, 217–223. doi: 10.1016/j.chb.2018.11.034

Liu, Y., Yue, S., Hu, X., Zhu, J., Wu, Z., Wang, J., et al. (2021). Associations between feelings/behaviors during COVID-19 pandemic lockdown and depression/anxiety after lockdown in a sample of Chinese children and adolescents. *J. Affect. Disord.* 284, 98–103. doi: 10.1016/j.jad.2021.02.001

Ma, J. Q., and Sheng, L. (2023). Internet use time and mental health among rural adolescents in China: a longitudinal study. *J. Affect. Disord.* 337, 18–26. doi: 10.1016/j.jad.2023.05.054

Mishra, S. K., Kapoor, L., and Singh, I. P. (2009). Telemedicine in India: current scenario and the future. *Telemed. e-Health* 15, 568–575. doi: 10.1089/tmj.2009.0059

Mutambara, D., and Bayaga, A. (2021). Determinants of mobile learning acceptance for STEM education in rural areas. *Comput. Educ.* 160:104010. doi: 10.1016/j.compedu.2020.104010

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Int. J. Surg.* 88:105906. doi: 10.1016/j.ijsu.2021.105906

Page, A., and Mosen, J. (2024). Addressing the challenges of conference participation for the Pacific: a regional approach to maximise attendance and participation. *Prof. Dev. Educ.*, 1–14. doi: 10.1080/19415257.2024.2332377

Pal, K. B., Basnet, B. B., Pant, R. R., Bishwakarma, K., Kafle, K., Dhami, N., et al. (2021). Education system of Nepal: impacts and future perspectives of COVID-19 pandemic. *Heliyon* 7:e08014. doi: 10.1016/j.heliyon.2021.e08014

Pratama, A. R., and Scarlatos, L. L. (2020). The roles of device ownership and infrastructure in promoting E-learning and M-learning in Indonesia. *Int. J. Mobile Blended Learn.* 12, 1–16. doi: 10.4018/IJMBL.2020100101

Ramos-Morcillo, A. J., Leal-Costa, C., Moral-García, J. E., and Ruzafa-Martínez, M. (2020). Experiences of nursing students during the abrupt change from face-to-face to e-learning education during the first month of confinement due to COVID-19 in Spain. *Int. J. Environ. Res. Public Health* 17:5519. doi: 10.3390/ijerph17155519

Rundel, C., and Salemink, K. (2021). Bridging digital inequalities in rural schools in Germany: a geographical lottery? *Educ. Sci.* 11:181. doi: 10.3390/educsci11040181

Safdar, S., Ren, M., Chudhery, M. A. Z., Huo, J., Rehman, H. U., and Rafique, R. (2022). Using cloud-based virtual learning environments to mitigate increasing disparity in urban-rural academic competence. *Technol Forecast Soc Change.* 176:121468. doi: 10.1016/j.techfore.2021.121468

Sierra-Díaz, J., González-Víllora, S., Toledo-Guijarro, J. A., and Bermejo-Collada, C. (2021). Reflections on the teaching and learning process in physical education during the COVID-19 pandemic. A real case. *Retos-Nuevas Tendencias Educacion Fisica Deporte Recreacion.* 41, 866–878. doi: 10.47197/retos.v41i0.85946

Smith, T. S. (1999). Rehabilitation outlooks for rural Louisiana: educational developments, economic trends, and global perspectives. *Work* 12, 199–211

Stubbé, H., Badri, A., Telford, R., Hulst, A., and Joolingen, W. (2016). E-learning Sudan, formal learning for out-of-school children. *Electronic J. e-Learn.* 14, 136–149.

Suraj, S., Kohle, S., Prakash, A., Tendolkar, V., and Gawande, U. (2024). Achievement motivation among health sciences and engineering students during COVID-19. *Ann. Neurosci.* 31, 36–43. doi: 10.1177/09727531231169628

Tardif, A. D., Gogovor, A., Guay-Bélanger, S., Audet, D., Parent, N., Gaudreau, A., et al. (2022). Integration of sex and gender in a continuing professional development course on diabetes and depression: a mixed methods feasibility study. *BMJ Open* 12:e050890. doi: 10.1136/bmjopen-2021-050890

Tosida, E. T., Herdiyeni, Y., and Suprehatin, S. (2022). Smart village based on agriculture big data analytic: review and future research agenda. *Int. J. Agric. Statistic. Sci.* 18, 515–538.

Van Eck, N., and Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* 84, 523–538. doi: 10.1007/s11192-009-0146-3

Wang, J., Tigelaar, D. E., and Admiraal, W. (2019). Connecting rural schools to quality education: rural teachers' use of digital educational resources. *Comput. Human. Behav.* 101, 68–76. doi: 10.1016/j.chb.2019.07.009

Wang, J., Tigelaar, D. E., and Admiraal, W. (2021). Rural teachers' sharing of digital educational resources: from motivation to behavior. *Comput. Educ.* 161:104055. doi: 10.1016/j.compedu.2020.104055

Wang, X., Young, G. W., Iqbal, M. Z., and Guckin, C. M. (2024). The potential of extended reality in rural Education's future–perspectives from rural educators. *Educ. Inf. Technol.* 29, 8987–9011. doi: 10.1007/s10639-023-12169-7

Wang, X., Young, G. W., Plechatá, A., Mc Guckin, C., and Makransky, G. (2023). Utilizing virtual reality to assist social competence education and social support for children from under-represented backgrounds. *Comput. Educ.* 201:104815. doi: 10.1016/j.compedu.2023.104815

Williamson, B., Eynon, R., and Potter, J. (2020). Pandemic politics, pedagogies and practices: digital technologies and distance education during the coronavirus emergency. *Learn. Media Technol.* 45, 107–114. doi: 10.1080/17439884.2020.1761641

Zhu, J., and Liu, W. (2020). A tale of two databases: the use of web of science and Scopus in academic papers. *Scientometrics* 123, 321–335. doi: 10.1007/s11192-020-03387-8