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The Utilisation of ICT Resources for Teaching and Learning Science in Rural Schools: A Bibliometric Analysis

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Abstract. Information and Communication Technology (ICT) offers pedagogical approaches in science that may enhance engagement in STEM disciplines. It has emerged as a catalyst for quality education and job creation, imparting scientific knowledge and potentially enhancing educational standards for rural students, hence generating increased opportunities for employment and entrepreneurship. This study aimed to explore research trends on the use of ICT in teaching and learning science in rural schools, using available big data on studies done in the past 10 years worldwide. A bibliometric analysis was used to analyse 171 journal articles and conference proceedings papers which were published or in press. These documents were obtained through the SCOPUS database. The keywords used were "ICT in teaching science" OR "rural schools". Data were organised into tables, graphs and visualisations obtained from VOSviewer, then analysed descriptively. Findings from the study revealed insufficient publications of documents in this area per year worldwide, citations and co-citations, poor collaborations and low total link strength for all documents published from 2013-2023. Whereas many studies have been conducted on the use of ICT or STEM education or rural education, few studies incorporated the three terms. Those who have embarked on these studies seem to be losing interest in doing more research in this area. Furthermore, there are insufficient collaborations between authors and countries in this research area. This study recommends that the amount of research and collaborations be increased on regarding the utilisation of ICT resources for teaching science in rural schools.

Keywords: ICT; teaching; science; rural schools

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1. Introduction

Utilising Information and Communication Technology (ICT) in science education has become essential to meet the needs of acquiring and applying knowledge to enhance global economies and to get ready for potential threats to contact classes such as COVID-19 and similar situations. Achor and Ityobee (2020) define ICT as the aspect of technology concerned with the handling and processing of information using various electronic devices to facilitate communication. An unprecedented shift in instructional techniques and knowledge representation was sparked by the introduction of ICT in education (Dlamini, 2022). ICT makes it easier to learn and assimilate information. Achor and Ityobee, (2020) posit that application of ICT in the educational sector has revolutionised the methods of teaching and learning in all subject areas. Whereas ICT was once limited to print media and shared by educators in the classroom, it is now accessible anywhere, anytime, and in any manner that suits anyone. It is used at all levels of schooling from primary schools to higher education institutions where it continues to be recognised as a technological and educational trend (Pelletieret al., 2021). Most of research done on the use of ICT in teaching and learning in rural schools is empirical research and little has been done on systematic literature reviews.

Technology is positioned in schools as a tool for improving teaching, learning and evaluation in novel ways (Lotherington et al., 2021) but Ghavifekr et al. (2016) found that teachers continue to face challenges when utilising ICT tools for teaching. ICT integration for education has faced some implementation obstacles in rural areas. Rural areas are characterised by unique challenges, including a high concentration of low socioeconomic status (SES), which exacerbate accesses to technology for these areas (Dolan, 2016), as well as small and often geographically isolated communities (Azano & Stewart, 2015). The challenges faced by rural schools are almost similar throughout the world. As a result, students and teachers residing in rural regions have fewer opportunities to utilise digital gadgets. Gillwald et al. (2018) argue that there is proof that those who are at the intersections of class, gender, race, or ethnicity are unable to harness the internet to enhance their social and economic wellbeing. Challenges with access and use of ICT in rural schools are, therefore, likely to affect teachers' digital skills and proficiency in using them for pedagogical integration. Furthermore, Hohlfeld et al. (2017) indicate that less access to internet for rural students restricts their usage of digital gadgets compared to their peers in urban and suburban areas. Rural schools encounter difficulties in recruiting and retaining trained teachers with strong teaching records (Du Plessis & Maestry, 2019). Among the competences necessary in the current teaching trends is the capacity to use ICT resources, but when teachers are not confident in the usage of ICT tools, they tend to have a lower perception of its value. This implies that they will not be used to their full capacity, thus creating an internal barrier (Harrell & Bynam, 2018).

Teachers may be reluctant to adopt teaching and learning technologies for a variety of reasons, including evaluations that still use outdated performance indicators; lack of training on how to use these technologies; lack of confidence

in using them; and their view of technology as a diversion from their regular teaching methods (Mahwai & Wotela, 2022). The urgency of education transformation to include ICT resources in all schools, as well as the challenges that have been reported regarding access to the use of ICT resources in rural areas, prompted an interest in this study to determine the amount of research that had been conducted on the use of ICT resources in teaching and learning in rural schools. Despite a call for greater study on the rural school-community, new studies in this area remain limited (Beach et al., 2018). Studies conducted on ICT in teaching in rural schools, using empirical studies or systematic literature review, revealed similar challenges because most rural schools face common challenges such as lack of resources, isolation and inability of these schools to attract competent science teachers (Shikalepho, 2020). The utilisation` of ICT in teaching and learning is expected to attract more research, based on its importance in improving 21st century teaching and learning strategies that require the use of ICT, or preparing for situations where education may be impossible to continue in a face-to-face setting. However, most studies done on teaching and learning in rural schools focus on either general education, science education or the use of ICT in teaching and learning. At the time of this study, there was insufficient documentation of the study's findings, including a review of the literature on the use of ICT in science education in rural schools. As a result, the expectation of this study was to stress clusters of study directions, both present and historical, as well as actual research demands. This study aimed to determine the scope of research conducted in the last ten years, from 2013 to 2023, on the use of ICT in teaching science in rural schools across the globe, using a bibliometric approach.

This study aimed to establish the state of research on the utilisation of ICT resources for teaching science in rural schools in the past decade through the following questions:

- Between 2013 and 2023, how many documents (journal articles and peer-reviewed conference proceedings) have been published regarding the utilisation of ICT resources for the purpose of teaching science in rural schools?
- How have the documents regarding the utilisation of ICT resources for teaching science in rural schools been cited and co-cited from 2013 to 2023?
- Between 2013 and 2023, was there enough collaborations regarding the utilisation of ICT resources for teaching and learning science in rural schools, as evidenced by the quantity of co-authored papers?
- How frequently were the keywords utilised from 2013 to 2023 that were significant for examining the application of ICT resources in teaching science in rural schools?

2. Literature Review

2.1 ICT and its resources

ICT is important in keeping up with the use and sharing of information and communication throughout the world. A broad range of technological instruments and resources used for information creation, sharing, transmission,

storing, and exchange are referred to as ICT. Examples include technological equipment such as computers, MP3/MP4 storage devices, satellites, world-wide-web, videos, CD-Rom, floppy disks and flash drives (Achor & Ityobee, 2020). Diverse and innovative technological advancements, also include artificial intelligence (AI), the Internet of Things (IoT), and virtual and augmented reality (AR), which have created new avenues for improving education (Gaol & Prasolova-Førland, 2021; OECD, 2021). ICT serves as an operational backbone that supports the major business activities/operations and is utilised to establish a digital services platform that enables rapid development and deployment of digital innovations (Sebastian et al., 2017). In a very short period, it has become the most fundamental component of modern industrial civilisation (Ghavifekr et al., 2014). As technology advances and becomes more versatile, ICT will continue to evolve and find new applications (Maharaj-Sharma & Sharma, 2017).

2.2 Affordances of ICT in education

ICT has resulted in a shift in educational approaches. It has arisen to transmit common knowledge and is a major incentive driving educational advancements (Haleem et al., 2022). Technologies used in education can give students access to digital knowledge and a virtual world that suits their learning preferences. In this way, students can be assisted to become lifelong learners. The ideal use of ICT resources to modify content allows for creative thinking, student participation and instructor knowledge gain (Molotsi, 2022): it offers opportunities for astute learning. Global education systems have made information and communication technology integration a higher priority in recent years and have done so by increasing investment (European Commission, 2019; Fernández-Gutiérrez et al., 2020; Lawrence & Tar, 2018). The convenience of adopting ICT is illustrated by allowing teachers and students to efficiently communicate via email, social media, blogs, or podcasts (Batista et al., 2021). Traditional classroom instruction lacks sufficient contact, prompt assessments, and an instantaneous learning atmosphere, thus ICT integration in education is thought to improve the learning environment by making it more relevant, pragmatic, self-directed, reflective and engaging. For example, teachers can use multimedia technology for content that deals with the digital representation and presentation of information using a range of media such as text, audio and video (Guan et al., 2018). This necessitates that educational institutions own digital devices, software, learning management systems and technological infrastructure (Fayez et al., 2021). If teachers do not have adequate access to ICT, however, they might be forced to resort to traditional teaching and learning methodologies (Chisango & Marongwe, 2021).

Several researchers have shown the efficacy of integrating and using ICT in the classroom. The usage of ICT in the school setting, mostly by teachers, results in a shift in the practice of these professionals (Powers et al., 2020). Utilising innovative teaching strategies and pedagogies, controlling and structuring the learning process, and getting access to useful information sources have all been demonstrated to be advantageous of an enhanced learning environment with technology (Casanova et al., 2020; Fayez et al., 2021; Mei & May, 2018). This can enable learners to process information in both verbal and graphical

representations employing tools found in presentations, lab or classroom learning, virtual reality, simulations, e-learning, and computer games (Alemdag & Cagiltay, 2018).

2.3 Integration of ICT in science teaching

ICT is incredibly helpful when teaching practical subjects where learners have to make observations of certain processes. For example, in science teaching and learning ICT tools, video demonstrations, and experimental simulations can mostly replace expensive laboratory supplies and reagents. Likewise, virtual laboratories are useful for pre-lab preparation and transferring knowledge and abilities from an idealised setting to physical reality (Makransky et al., 2016). ICT-facilitated simulations make it simple to experience laboratory demonstrations that cannot be carried out in a classroom setting. Many scientific processes, concepts and applications can be explained in almost lifelike detail through video clips (Maharaj-Sharma & Sharma, 2017). ICT can draw students in and hold their interest longer than instructor discourse because of its visual appeal, which can captivate students' attention and help them concentrate. When using virtual labs, the most beneficial learning outcome is conceptual knowledge and they increase students' motivation, self-efficacy and attitudes towards learning (Byukusenge et al., 2022). However, despite educators' realisation of the potential of ICT to increase student engagement, their technology is not consistently and successfully integrated into educational activities (Maharaj-Sharma & Sharma, 2017). When they are used, they are mostly employed to strengthen, improve and supplement traditional classroom methods rather than to alter the objectives, pedagogies, or subject matter.

2.4 Limitations of using ICT in rural schools

The 21st century brought a rapid improvement of ICT tools for communication, creation, dissemination, storing, management and information search (Ratheeswari, 2018). However, many rural schools in developing nations still struggle with access to and availability of ICT infrastructure and this continues to remain a problem. Hence, the Department of Basic Education in South Africa is intervening through increased provision of ICTs (Chisago & Lesame, 2017). Even though, South Africa boasts about investments of ZAR 23.8 billion from mobile operators alone (Gillwald et al., 2018), access to the internet is still a challenge in many rural schools. Challenges associated with the use of ICT in teaching may not be the same for all countries, but even developed countries have some challenges. Most countries, especially those of the third world, find it challenging to integrate ICT into science teaching and learning in rural schools due to the digital divide and lower funding that divides rural schools from their counterparts in suburbs and cities. For example, even though rural areas in America are now more wired than they were in the past, Vogels (2021) noted that many rural areas lack consistently stable broadband connectivity due to current infrastructure. Consequently, in regard to inequality in internet availability, children in rural regions have fewer opportunities than their counterparts in urban and suburban areas to use digital devices (Powers et al., 2020). Hampton et al. (2021) indicated that inequalities in internet access will serve as an additional factor in the concentrated disadvantage experienced by

rural youth due to the lower socioeconomic status of rural communities. This may reduce interest and trust in these technologies. The difficulty of providing technology infrastructure for teaching and learning in rural schools makes it costly (Pholoto & Mtsweni, 2016).

The digital skill sets of instructors in rural areas and the ICT infrastructure found in schools vary significantly as well. In some parts of the world, there are some rural schools that have ICT resources; however, access to ICT infrastructure does not inherently imply that an individual possesses ICT skills or utilises the infrastructure (Chisango et al., 2019). Teachers' attitudes towards ICT were found to predict whether they used technology in the classroom. Marongwe et al. (2019) discovered that some experienced educators preferred using the chalkboard and textbook. Furthermore, older seasoned teachers stated that young college and/or university teachers were most suited to using ICT in teaching and learning. This inherently suggests that students instructed by such educators will lack exposure to ICT in their learning, resulting in their lagging behind while others advance. Basic understanding of mobile technologies is another challenge for teachers in rural schools, because, even when these are provided, teachers do not attempt to integrate technology into teaching and learning (Herselman, et al., 2019). To revolutionise teaching, schools need to be equipped with tablets, laptops, desktop computers, data projectors, fully functional computer labs and interactive digital whiteboards.

3. Research Methodology

3.1 Research approach

A bibliometric analysis was used to extract data from documents that focused on the use of ICT in teaching and learning of science in rural schools. A bibliometric analysis assessed various scientific items (e.g., papers, authors, keywords, journals, institutions and countries), analysing how the relationships and interactions between these items have shaped the intellectual, social and conceptual structure of the relevant field over time (Donthu et al., 2021). Aria and Cuccurullo (2017) added that a bibliometric analysis allows for the examination of hundreds or thousands of papers. Since large data are used in a bibliometric analysis, a macro-level approach was suitable for this study. According to Leung et al. (2017), Xu et al. (2018) and Donthu et al. (2020), bibliometric analysis aids in the full understanding of a study field, boundary mapping, author identification and the discovery of new avenues for future research. Its goal is to identify, assess and comprehend the literature or a portion of it within a certain topic of study (Öztürk et al., 2024). This allowed me to provide a detailed review of many documents for my study. All documents extracted for this study were those that only focused on the teaching and learning of science, rural education and use of ICT in teaching and learning.

Data for this bibliometric analysis study were extracted from the Scopus database, an abstract and citation database of peer-reviewed books and online resources with tools for tracking, analysing, and visualising research (Baas et al., 2020). Furthermore, Scopus content is subjected to a thorough review procedure and selected in accordance with rigorous and high-quality scientific criteria. This

study only reviewed journal articles and conference proceedings that have been peer reviewed. Access to a large collection of international peer-reviewed content is made possible via Scopus(ASU, 2022) which provides access to a broad portfolio of peer-reviewed content from around the world. Since a bibliometric analysis requires huge data, it was easier to obtain these data from Scopus for this study.

3.2 Search string

A search string is a collection of search phrases, operators and modifiers used to query a database or search engine for relevant results. To find related literature, a Boolean search was utilised, coupled with keywords comparable to those in the study's title. A Boolean search uses operators (words and symbols) like AND or NOT that allow you to broaden or narrow your search parameters while utilising a database or search engine. The keywords used to search for papers were "ICT in teaching science" OR "Rural schools". Scopus provided other keywords from which I filtered the following for a more precise search: rural; education; teaching; schools; school; rural school; rural areas; learning; e-learning; curriculum; high school; science education; secondary education; primary school; curricula; middle school; small schools; secondary schools; rural teachers; and secondary school. The search string used followed the process in Figure 1 below.

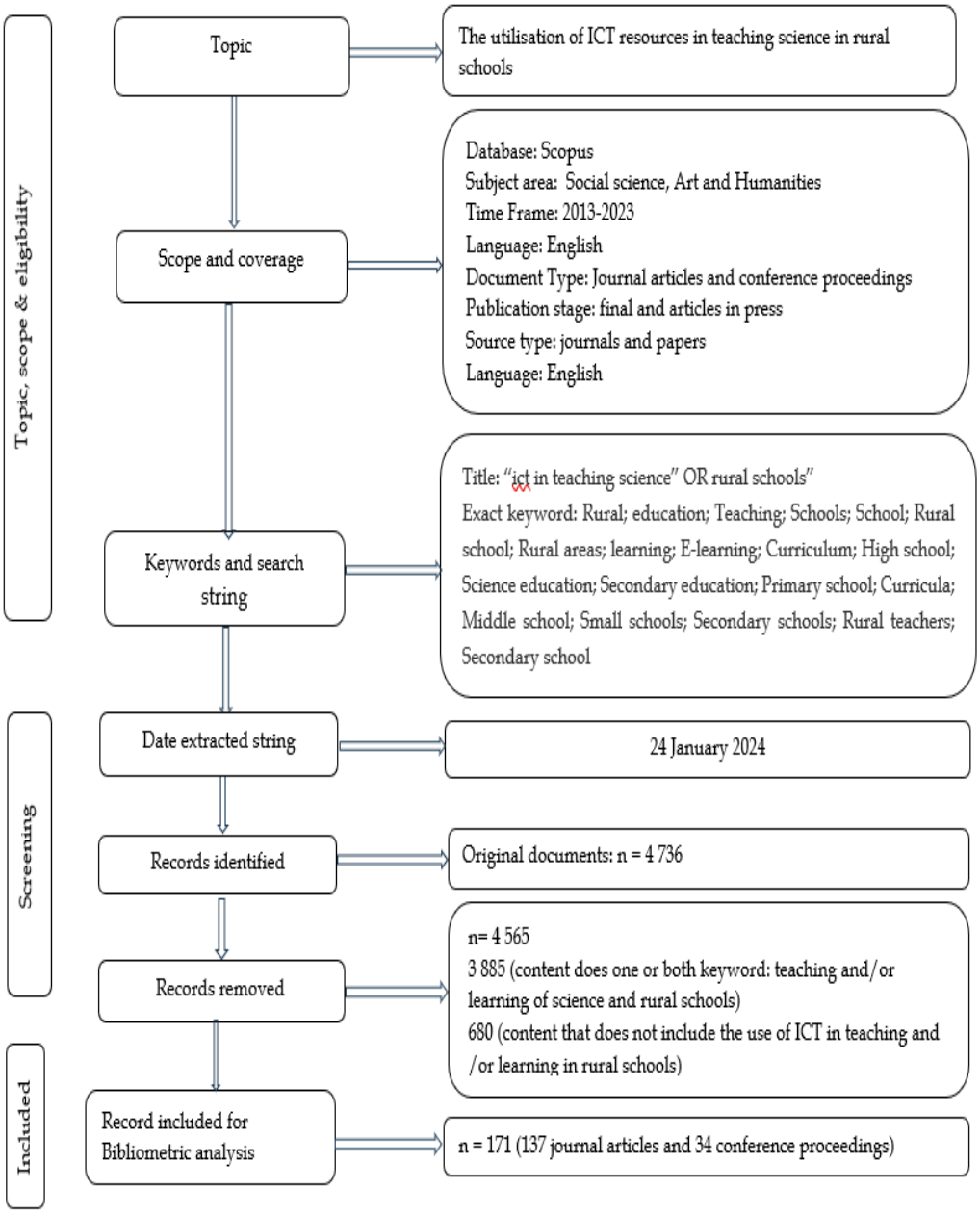

Figure 1: Search strategy

3.3 Inclusion criteria

Only peer reviewed journal papers and conference proceedings that were either published or in press (have been given the go-ahead for release), were selected for this bibliometric analysis study. The choice of journal articles was premised on the fact that they are peer reviewed and filtered to separate high-quality research from flawed or unreliable work. Research articles that underwent the peer review process before publication were considered more credible as they went through stringent quality control checks to ensure that only relevant and verified research reaches the academic community (Discovery. Life, 2023). Peer reviewed conference proceedings were also chosen because they are regarded as

equally useful sources of knowledge. They can also be divided into two groups: those that are published as special editions or monographs, and those that are accepted for regular issues (Purnell, 2021). Conference reviewers are usually professionals in the same field as the authors and are qualified to evaluate the scientific value of the research presented. The documents in this study were limited based on the inclusion criteria listed in Table 1 below.

Table 1: Inclusion criteria (extracted from Scopus on 24th of January 2024)

Range	Subject area	Document type	Publication stage	Keywords	Countries	Affiliation	Language
2013-2023	Social science Art and Humanities	Articles Conference papers	Finalised In press	Only those referring to teaching and learning, schools, rural and ICT/e-learning	All	All	English

A range of 10 years was placed to establish recent publications that were done on the research topic. Additionally, education policies, teaching and learning trends may change over the years so 10 years was reasonable for any change, hence a bibliometric analysis of studies that have taken place within the past 10 years. Teaching and learning at school level fall within social sciences as well as art and humanities, consequently documents falling under these studies were chosen. The most trustworthy sources of information were those that had been finalised, published, or had been given the go-ahead for release. I exclusively use English for instruction and learning, which is why documents chosen were either written or translated to English.

3.4 Data analysis

Data extracted manually from Scopus were analysed using a table to establish publications done between 2013 and 2023, as well as using the VOSviewer 1.6.9, a software tool that allows you to create maps from network data and then visualise and explore them (Van Eck & Waltman, 2022). A map can be constructed based on an already available network. A network can be built using bibliographic database files (such as Web of Science, Scopus, Dimensions, Lens and PubMed files) and reference management files (such as RIS, EndNote and RefWorks files). For this study, only the Scopus database was used. VOSviewer is particularly well-suited for visualising bigger networks since it offers distance-based visualisations instead of graph-based ones (Van Eck & Waltman, 2014). The three VOSviewer visualisations include: network, overlay and density visualisations ((Van Eck & Waltman, 2022). VOSviewer allows you to create networks of scientific publications, journals, researchers, research organisations, nations, keywords and concepts. Items in these networks can be linked via co-authorship, co-occurrence, citation, bibliographic coupling, or co-citation linkages. The weight of an item also represents its importance. There are two common weight attributes: links and total link strength. For a given item,

the links and total link strength qualities represent, respectively, the number of links that an item has with other items and the total strength of those links.

Utilising co-authorship, co-occurrences, citation, co-citations and bibliographic coupling, bibliometric analysis was performed in this study. Tables obtained using data extracted from Scopus and VOSviewer were analysed descriptively according to trends of information provided. Bibliometric data from VOSviewer that could be extracted from the overlay visualisation and network visualisation were analysed thematically as well. The total link strengths (TLS) were used to compare citations that linked to other authors' work. TLS quantifies how strongly one article or researcher is linked to other publications and researchers (Vallaster et al., 2019; Van Eck & Waltman, 2014). VOSviewer can be obtained from www.vosviewer.com.

4. Findings and Discussion

4.1 Publications by year

All documents were based on the use of ICT in teaching science for studies done at rural schools or institutions of learning and were related to learners/students and teachers or lecturers. Table 2 shows the number of documents extracted manually from Scopus from published journal articles or conference proceedings and those that were in press. Out of the 171 documents extracted from Scopus, 137 were journal articles and 34 were conference proceedings, the rest were published articles. Table 2 provides a summary of publications relevant to this study published between 2013 and 2023.

Table 2: Publications per year from 2013-2023 (extracted from Scopus on 24th of January 2024)

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Documents per year	6	7	14	14	7	15	22	22	19	21	24
(+: increase; -decrease) of documents		+1	+7	0	+7	-7	+8	0	-3	+2	+3

Figure 2 shows the trend of publications between 2013 -2023

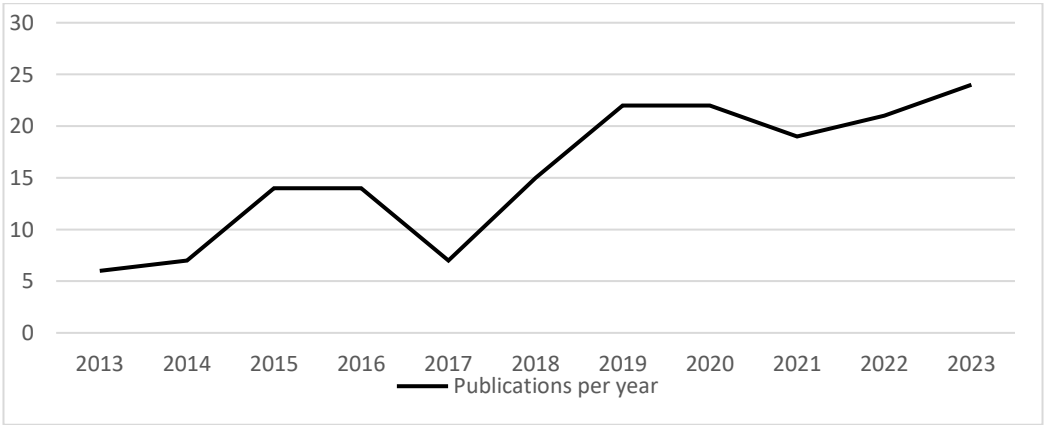

Figure 2: The trend of documents published between 2013-2023

Few documents have been published on the use of ICT between 2013-2023. The number of published documents range from 6 to 24; this is too low given that this is a study based on global research captured by one of the largest databases. The number of documents published in these years is inconsistent although there has been a slight increase between 2018-2023 compared to 2013-2017.

4.2 Citation analysis

A citation analysis determines the degree of acceptance of a publication by measuring how frequently it appears in other published reports (Xu et al., 2018). The citation analysis was obtained from Scopus and VOSviewer using citation per year and citation by source.

4.2.1 Citations per year

Even though the documents acquired have been cited at least once, the number of citations has fluctuated over the last ten years, with a significant increase from 2020 to 2021, followed by a reduction from 2021 to 2022, and a further decrease in 2023. The increasing frequency of zero citations, as well as a decrease in cited documents, particularly between 2021 and 2023, show that forthcoming scholars' interest in this area of study is waning. This occurred despite an increase in papers from 2013 to 2023, with 36 documents receiving no citations, the greatest amount recorded in 2023. The number of citations ranged from 7-54. Table 3 also shows that the number of publications does not necessarily mean more citations.

Table 3: Citations per year from 2013-2023 (extracted from Scopus on 24 January 2024)

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Documents per year	6	7	14	14	7	15	22	22	19	21	24
0 citations	1	1	1	1	1	2	4	2	2	7	14
Highest cited document (at least once)	54	41	35	52	15	38	64	26	162	17	7

In 2021, the 19 documents in this study were cited 162 times, whereas in 2019, 2022 and 2023 more documents were published but they had fewer citations. Figure 3 below shows the trends of citations on the utilisation of ICT resources for teaching and learning science in rural schools from 2013-2023.

In a period of 10 years, the highest number of cited documents available on the use of ICT:

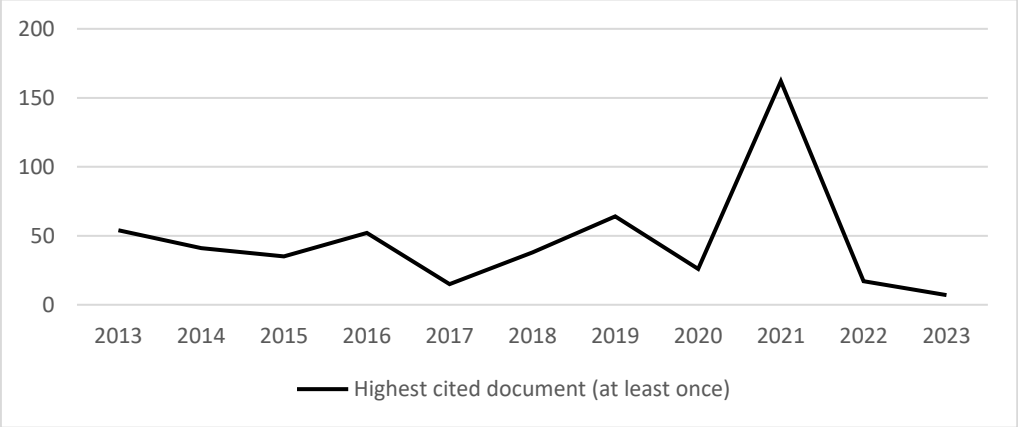

Figure 3: Citations per year for documents published between 2013 and 2023

While studies on the use of ICT have attracted research, findings for this study reveal that this has not been the case on studies related to the utilisation of ICT resources for teaching and learning science in rural schools. These studies do not seem to be attracting more readers as well, which is evident in citations. The findings support those of Rei et al. (2018), which revealed that, although the digital transformation has expanded to all sectors, some have greater potential for future development than others.

4.2.2 Citation by source

VOSviewer was used to analyse citation of documents by source, which assisted in ensuring that studies analysed were relevant for this bibliometric analysis. The analysis for the citation by source was based on a minimum five documents by sources and two minimum citations of a source. As such, from 136 sources, only three met the threshold. The zero TLS implies that, even though these articles are highly cited, they are not linked to other publications and researchers (Vallaster et al., 2019; Van Eck & Waltman, 2014). Table 4 below shows sources that met the threshold from the highest to the lowest citation.

Table 4: Citation by source (extracted from Scopus on 24 January 2024)

Sources	**Number of documents**	**Number of citations**	**TLS**
Rural Special Education	7	117	0
Education and Information Technology	5	213	0
Computers and Education	5	143	0

The total number of documents that contain information relevant for this study obtained from Scopus was 12, too little considering that the research was based on global literature. The number of documents cited twice for each source is more than 100 but, based on the breadth of the study, this is insufficient. All sources have TLS of 0, implying that information from these sources may not be linked to cover all aspects of studies on the use of ICT resources for teaching and learning in rural schools

4.3 Bibliographic coupling and co-citation analysis

Bibliographic coupling happens when two works reference the same third work in their bibliographies (Surwase et al., 2011). Sahu (2021) indicates that it relates to how objects' connectedness is quantified by the number of references they share. This suggests that there's a good chance the two pieces address similar topics. If two documents cite the same document or papers together, they are considered bibliographically linked. When a document receives more citations, the stronger its relatedness (coupling) becomes. It discusses the parallels between the two works in terms of documents, sources, writers, organisations and states (Sahu, 2021). Co-citation analysis reveals interdisciplinary research patterns inside by forming paradigms or clusters. When paired with multidimensional scaling and single link clustering approaches, co-citation analysis literally portrays the organisation of science and specialised research topics (Surwase et al., 2011). This study only analysed bibliographic coupling and co-citation by document

4.3.1 Bibliographic coupling and co-citation by document

The bibliographic and co-citation information for this publication were obtained from the Scopus database and analysed using VOSviewer 1.6.19 software. Table 5 shows the bibliographic coupling by document for this study arranged according to link strengths.

Table 5: Bibliographic coupling and co-citation by author (extracted from VOSviewer 1.6.19 on 24 January 2024)

Authors	Co-citations	Year of publications	TLS
Mo, D., Zghang, I., Luo, R., Qu, Q., Huang, W., Wang, J., Qiao, Y., Boswell, M., Rozelle, S.	34	2014	5
Lai, F., Zhang, I., Hu, X., Qu, Q., Shi, Y., Qiao, Y.,Boswell, M., Rozelle, S.	30	2013	5
Bai, Y., Mo, D., Zhang, I., Boswell, M., Rozelle, S.	52	2019	5
Wang, J., Tigelaar, D.E.H., Admiraal, W.	63	2019	5
Li, G., Sun, Z., Jee, Y.	38	2019	1
Yang, J., Yu, H., Chen, N.S.	57	2019	1
Stenhoff, D.M., Penington, R.C.	50	2020	0
Scully, D., Lehane, P., Scully, C.	51	2021	0
Adarkwah, M.A.	162	2021	0
Michelle, C., De Lange, N., Moletsane, R.	43	2016	0
Bice-Urbach, B.J., Kratochwill, T.R.	50	2016	0
Vernon-Feagans, I., Kainz, K., Hendric, A., Ginsberg, M., Amendum, S.	54	2013	0
Panyajamorn, T., Suanmali, S., Kohda, Y., Chongphaisal, P., Supnithi, T.	38	2018	0
Kissi, P.S., Nat, M., Armah, R.B.	37	2018	0
Pereira, S., Fillo, J., Moura, P.	104	2019	0
Resta, P., Laferriere, T.	35	2015	0
De la Varre, C., Irvin, M.J., Jordan, A.W., Hannum, W.H.	41	2014	0

For 30 co-citations, 17/175 documents of authors met the threshold. Data on co-cited documents for this study show that the highest number of co-cited documents was in 2021(162), whereas the lowest was in 2013 (30). Out of 17 co-cited documents by authors, 11 had 0% TLS, meaning that these studies are not considered important by most academics because they are not linked to other researchers or publications (Vallaster et al., 2019).

The number of documents presented in Table 4 was added up per year to reveal the number of documents co-cited per year. Data revealed that 939 were co-cited 30 times or more between the year 2013 and 2021. More co-citations were done in the years 2019 and 2021. No document was co-cited in 2022 and 2023. Table 6 shows the breakdown of documents co-cited per year during this period.

Table 6: Documents co-cited 30 times or more per year

2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
84	75	35	93	0	75	314	50	213	0	0

The data show that the interest in co-citing topic of ICT in teaching and learning science in rural schools is not consistent and has not been there in the last two years (2022-2023). However, there were satisfactory data on documents that were co-cited in 2019 and in 2021. The analysis of co-citations by year in Figure 4 below shows fluctuting increase and decrease of documents that have been co-cited 30 times and more.

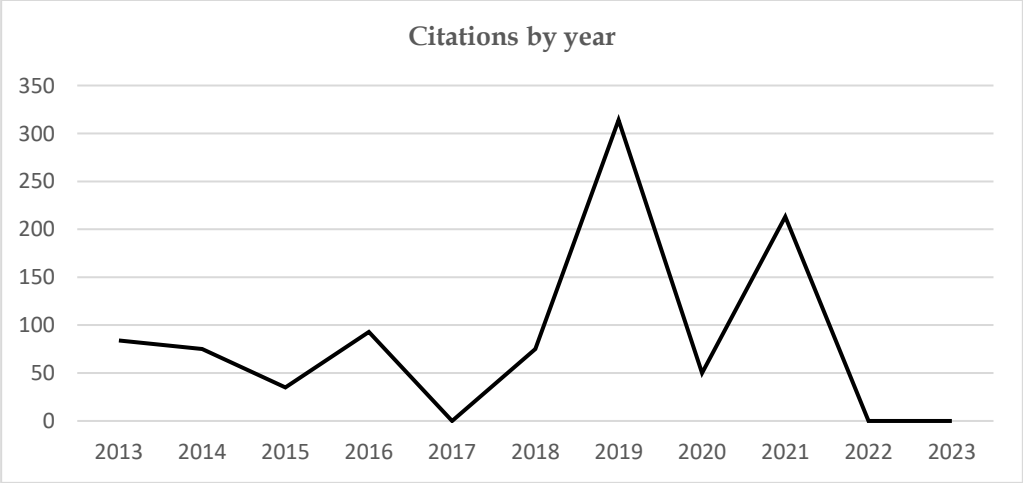

Figure 4: Documents co-cited 30 times or more

Figure 5 shows the overlay visualisation for documents co-cited 30 times or more

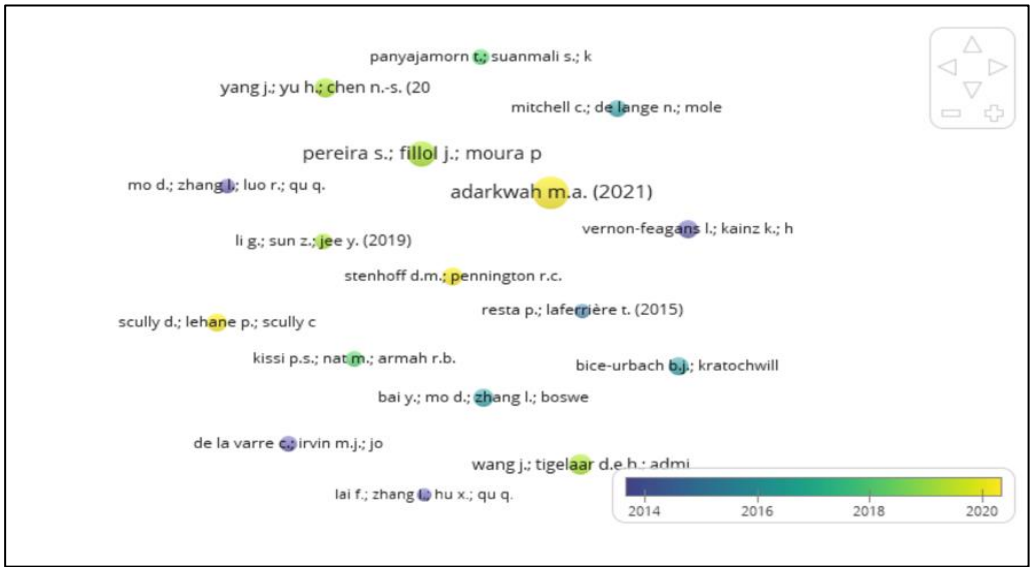

Figure 5: Overlay visualisation of citations by source (taken from VOSviewer 1.6.19 on 24 January 2024)

Although Lai et al., Mo et al., Bai et al., a Wang et al. and Li et al. do not have the highest number of co-cited documents, their documents have strong TLS of links that exist. Their documents were published in 2013, 2014 and 2019, respectively. Li et al. and Yang et al. have weak TLS of 1 because they are only linked to Wang et al. An overlay visualisation of all linked co-cited documents is shown in Figure 6.

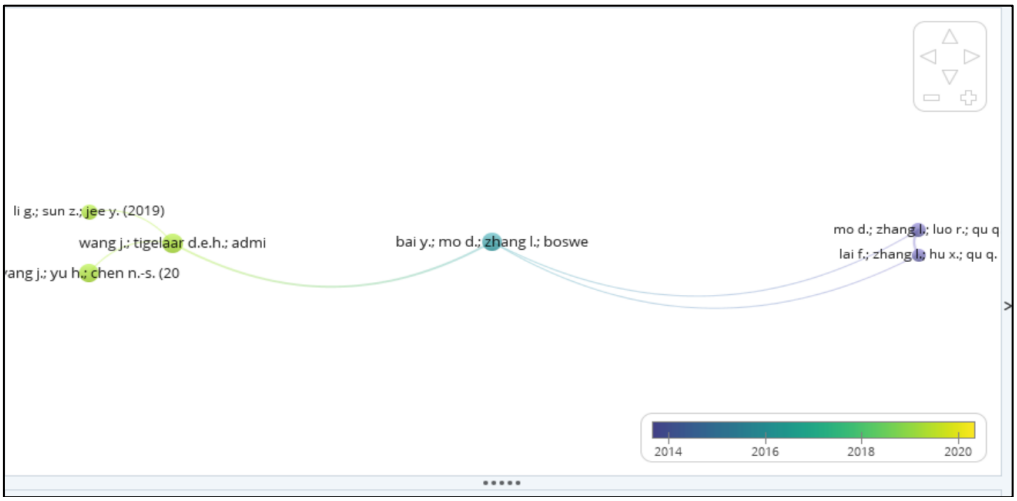

Figure 6: Network visualisation of bibliographic coupling by document (taken from VOSviewer 1.6.19 on 24 January 2024)

4.4 Co-authorship analysis

Martínez--López et al. (2018) indicate that co-authorship analysis determines the units with the highest degree of collaborative publications and measures the most productive group of papers. The co-authorship analysis is organised according to the categories below. This study focused on co-authorship by author, co-authorship by organisations and co-authorship by countries.

4.4.1 Co-authorship by author

Table 7 shows data obtained for authors who published at least two documents and had a minimum of three citations.

Table 7: Co-authorship by author (extracted from VOSviewer 1.6.19 on 24 January 2024)

Author	Document	Year of publication	Citations	TLS
Wang, J., Tigellaar, D.E.H., and Admiraal, W.	3	2022	97	0
Meyer, B.	2	2015	15	0
Boz, T. Allexsaht-Snider, M.	2	2023	4	0

According to the Scopus database, 3/171 authors met the threshold for this study. The total number of citations for a minimum of three documents and a maximum of three documents was 116. This was insufficient for all studies that contained relevant information for this study. The total link strength (TLS) for all authors was zero. The data presented in Table 7 show weak collaborative publications by authors and no links to other publications and researchers in this area of study, implying that these documents were not linked to other researchers' work.

4.4.2 Co-authorship by organisations

The analysis in Table 8 below is based on two documents per organisation with a minimum of two citations; 6/353 organisations from six countries met the threshold set. All organisations had only published two documents were cited at least twice.

Table 8: Co-authorship by organisations (extracted from VOSviewer 1.6.19 on 24 January 2024)

Organization	Country	Documents	Citations	TLS
Center for Studies in Education and Psychology of Minorities in Southwest China	China	2	34	1
Leinden University Graduate School of Education and Psychology	Netherland	2	91	1
Department of ICT, University of Education, Winneba	Ghana	2	40	0
Sirindhorn International Institute of technology	Thailand	2	39	0
University of Melbourne	Australia	2	12	0
University of the Free State	South Africa	2	24	0

The highest citation was 91 and the lowest was 12. This is low for a global study. Only studies done by the Center for Studies in Education and Psychology of Minorities in Southwest China and Leinden University Graduate School of Education and Psychology in the Netherlands had a TLS of 1 whilst the rest had zero. This means that, in addition to few documents and low citations, studies done by these organisations are not linked to each other or other researchers. For

the past two years (2022 and 2023) no organisation met this threshold. Figure 7 shows the overlay visualisation extracted from VOSviewer 1.6.19.

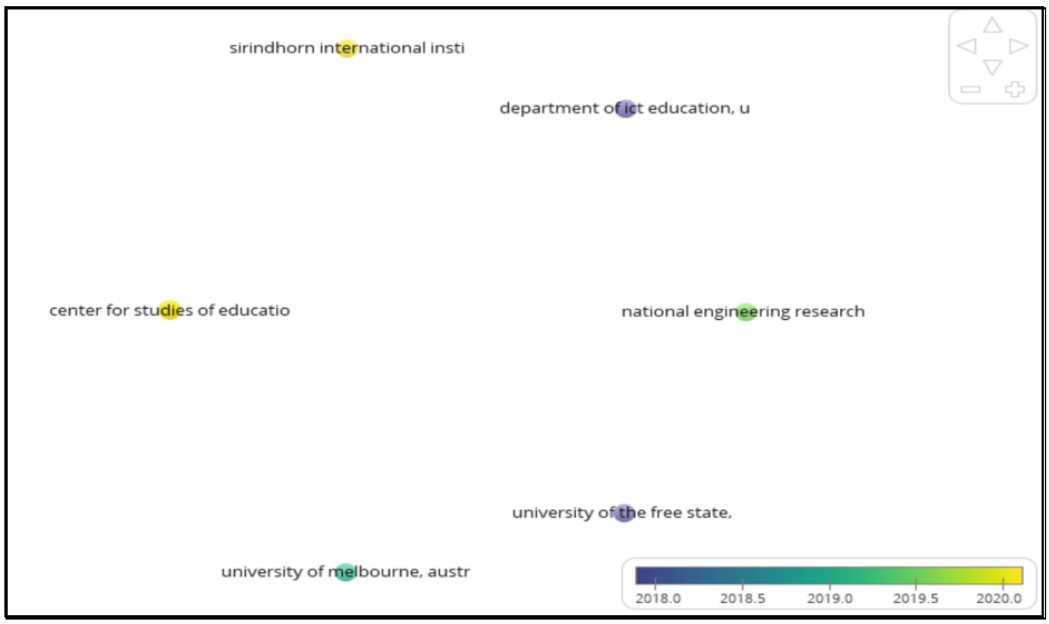

Figure 7: Overlay visualisation of co-authorship per organisation (taken from VOSviewer 1.6.19 on 24 January 2024).

4.4.3 Co-authorship by countries

The analysis in Table 8 shows countries that published five documents which have at least two citations. Ten countries met the threshold. Table 9 has arranged them according to decreasing TLS.

Table 9: Co-authorship by countries (extracted from VOSviewer 1.6.19 on 24 January 2024)

Country	Document	Citation	TLS
United States of America	57	694	8
China	28	443	7
New Zealand	5	49	6
Australia	8	88	3
Indonesia	5	22	3
Spain	12	58	3
Malaysia	6	37	2
United Kingdom	6	44	2
South Africa	21	157	1
Thailand	7	42	1

The data presented showed that the USA has published the most articles followed by China. These are the only countries where there is correlation in the number of documents published, citations and the TLS. The least cited country from the list was Thailand but it has more documents that the United Kingdom, Malaysia, Indonesia and New Zealand. Whereas, while South Africa was in third place in terms of the number of documents and citations, it had a weak TLS of 1. However, New Zealand had the least documents, and was in sixth place

with 44 citations), placed third with TLS after China. This discrepancy in number of documents, citations and TLS showed that networks for many countries are weak.

The overlay visualisation of citations by countries in Figure 8 below shows that the citations of the top ten cited countries took place between 2019 and 2022.

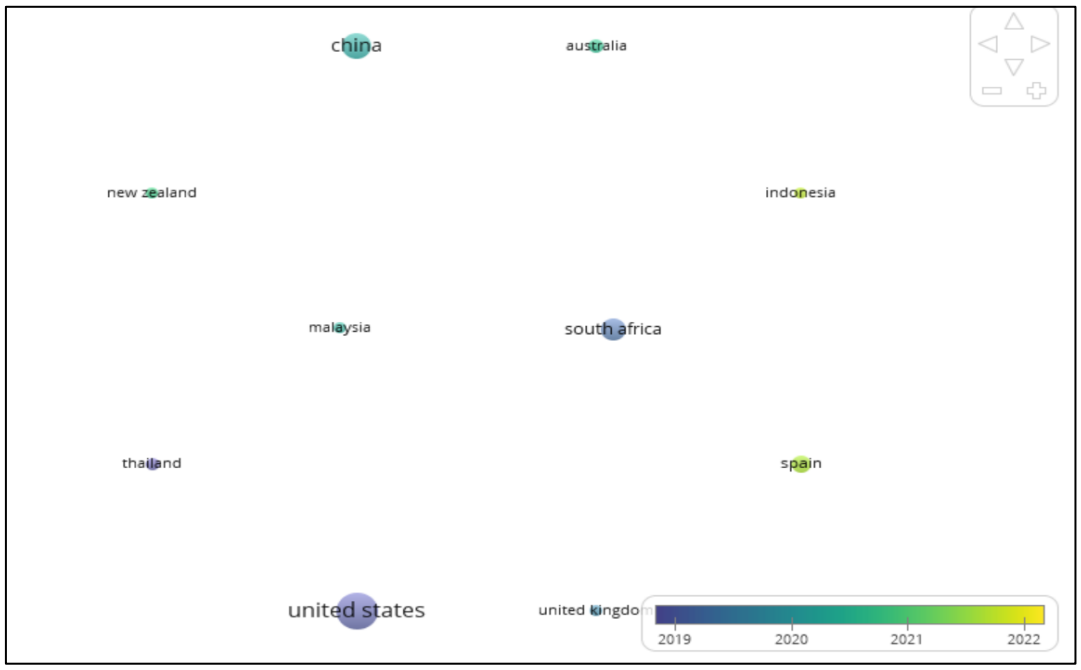

Figure 8: Overlay visualisation of the most cited countries (taken from VOSviewer 1.6.19 on 24 January 2024).

The USA, South Africa and Thailand published between 2019 and 2020, followed by China, Australia, New Zealand, Malaysia and the UK between 2020 and 2021, then Spain between 2021 and 2022 and Indonesia in 2022. The network visualisation below shows that networks exist only between 8/10 countries that met the threshold, yet these are predominantly weak.

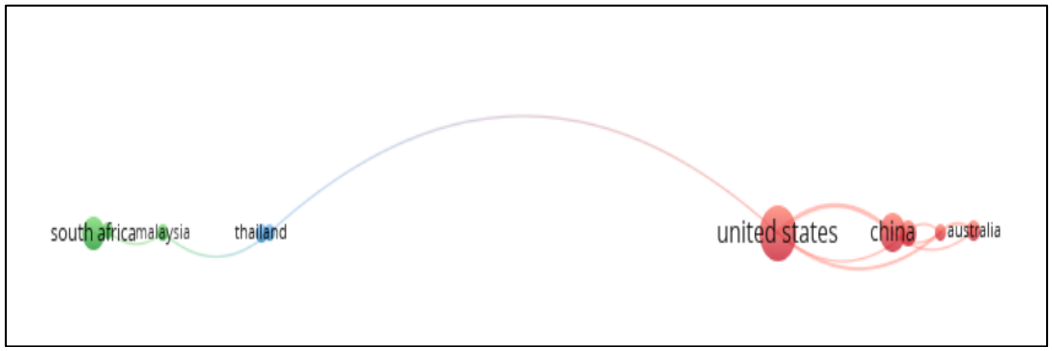

Figure 9: Network visualisation of the most cited countries (extracted from VOSviewer 1.6.19 on 24 January 2024).

Some networks displayed in Figure 9 indicate the presence of collaborative clusters and quantify the extent of joint publications between countries that

contributed to knowledge advancement in this field of study (Caviggioli & Ughetto, 2019). There are strong networks between the United States, China and Australia, as well as strong networks between South Africa, Malaysia and Thailand, but the links between the two groups are weak.

4.5 Co-occurrences analysis

Co-occurrences measure the frequency of keywords (Callon et al., 1991). Only occurrences by author keywords were analysed for this study because it contained the most relevant information required for this study.

4.5.1 Number of occurrences by author keywords

For 10 co-occurrences, 15 keywords met the threshold. Table 10 and Figure 10 show the top 14 authors, which have occurrences of between 5 and 21 and is arranged according to decreasing TLS.

Table 10: Co-occurrences by author keywords (verified selected keywords extracted from VOSviewer 1.6.19 on 24 January 2024)

Keywords	Occurrences	TLS
Rural schools	21	10
Online learning	9	9
Rural education	14	8
COVID-19	10	7
Technology	10	6
Elementary education	6	5
Professional development	8	5
Teacher professional development	6	5
Digital divide	5	4
Distance education	5	4
ICT integration	5	4
Rural	7	4
Teachers	7	3
Rural schools	9	2

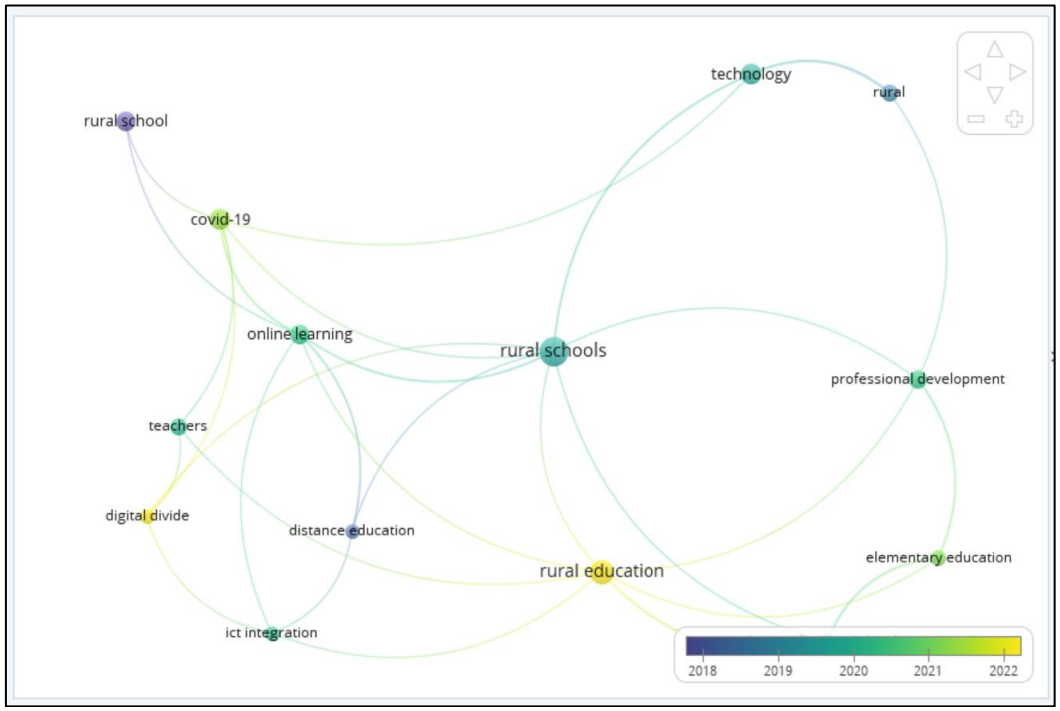

Figure 10: Occurrences of all keywords (taken from VOSviewer 1.6.19 on 24 January 2024)

The network analysis showed four clusters according to all keywords that overlap in the years between 2018 and 2022. Cluster 1 is identifiable by the colour purple and consisted of the keywords: rural schools and distance education. Studies containing these keywords were generally conducted between 2018 and 2019. Cluster 2 is identifiable by a green colour for studies between 2020 and 2021. The keywords under this cluster were: rural, ICT integration, online learning, and technology, rural and professional development. Cluster 3 is identified by a greenish yellow colour. These were studies done between 2021 and 2022. The keywords under this cluster were COVID-19 and rural education. Cluster 4 is identified by a yellow colour and has the keywords rural education and digital divide. The strongest networks were between keywords: rural schools, rural education, COVID-19 and online learning. According to Van Eck and Waltman (2014), terms that are closer together indicate (and positively correlate with) higher levels of co-occurrence. The least keywords used were digital divide, distance education and ICT integration with five occurrences. The keywords indicated that the studies extracted were focused on the teaching and learning using ICT in rural schools, which is the focus of this study

5. Conclusion and Recommendations

Findings from the search done in January 2024 revealed inconsistencies and insufficiency in publications done between 2013-2014. There has not been a year where the number of publications exceeded 30. The number of cited articles decreased drastically from 2021-2023, which could mean that the lack of interest in this area of study is increasing. Even when considering at least one citation per document, there were documents not cited at all in a year. With regard to

collaboration amongst researchers, this study has been lacking. The bibliographic coupling and co-citation analysis revealed that only a few documents were linked. This is evidence that researchers are not interested in citing each other's work. Low TLS exists in citations, co-citations and co-authorship except co-authorship by countries. This means that research in studies on the utilisation of ICT resources for teaching and learning science in rural schools is kept within individual countries or that studies focus on either science or the utilisation of ICT in teaching or that many studies do not necessarily focus on rural schools only or that many researchers worldwide are losing interest in this topic. Utilising ICT resources to teach science is still a challenge for most teachers, yet the number of publications, poor collaborations and citations implies that this study does not attract novice researchers, nor does it keep previous researchers in this area. This bibliometric analysis hopes to influence more researchers to write more papers, co-author and cite each other's work. Additionally, the exposure of this study might persuade education stakeholders to reconsider aligning the curriculum to better fit rural schools in terms of teaching and learning resources and access to other sources of knowledge. These changes are expected to encourage research in this subject as well as international collaborations.

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I confirm that this paper is my own work and has not been published elsewhere

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