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The challenges and solutions of technology integration in rural schools: A systematic literature review

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ABSTRACT

The digital divide between urban and rural schools challenges efforts to promote technology integration in education, and contributes to growing educational inequity in many contexts. Using the most current version of Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA 2020), we identified and extracted 36 articles and conference papers on the use of technology in rural schools from the Scopus and Web of Science databases. We used Critical Interpretive Synthesis to identify the challenges and solutions involved in integrating technology in rural schools. The analysis revealed 29 challenges, which were categorized using the framework of the ecological perspective into macro level, *meso* level, and micro level challenges. The analysis also identified solutions to the challenges discussed in these studies. By focusing on the challenges and proposed solutions at different contextual levels, this review is intended to identify what constitutes good practices when integrating technology in rural schools. Future research should focus on factors which facilitate the use of technology and how the integration of technology impacts students' learning experiences and achievement in rural schools.

1. Introduction

Technology-assisted learning has been promoted as an innovative education practice for more than a century because it has the potential to enhance teaching and students' learning experience, which ultimately leads to better student learning achievement (Rubach et al., 2022; Sanfo & Malgoubri, 2023). Relevant studies have highlighted how teachers promote student-centred learning through online collaboration to motivate students and improve their learning (Kormos & Julio, 2020). Technology can also mitigate a lack of classroom facilities. For example, projectors and computer labs can be replaced, to some extent, with simple, non-commercial Learning Management Systems (LMS) which are accessible on smartphones, such as Google Classroom. Consequently, technology-assisted learning is increasingly playing a critically important role in education.

Despite the significant contributions of technology to learning and teaching, there is a well-known technological disparity between schools in rural and urban areas. The differences include how technology is used (Chen et al., 2019), whether learning activities are supported with different technologies (Xu et al., 2020), teachers' technological literacy (Thannimalai et al., 2022), students' ICT skills (Bayor et al., 2023), and how frequently teachers use technology (Kormos & Wisdom, 2023). As these prior studies have identified, teachers in rural schools do not use technology as much as those in urban schools due to their limited training (Rana et al., 2022). Both students and teachers in rural areas need to develop technological skills and positive dispositions towards using technology for

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educational purposes. It should also be noted that the disparity between urban and rural schools was escalated by the emergency switch to online learning during the COVID-19 pandemic, contributing to a significant learning deficit among students with less privileged socioeconomic backgrounds (Avanesian et al., 2021; Betthäuser et al., 2023; Tao & Gao, 2022).

The problems of technology integration are complex and involve schools, teachers, and students. Some problems overlap among these three stakeholders, but each may undermine the application of technology in rural schools. By launching technology integration initiatives, schools play a role in obtaining funding from government and non-government institutions to acquire technological infrastructure, such as computers (Kerimbayev et al., 2016) and internet connection (Srinivasan et al., 2021). In some cases, schools also decide which technologies are to be used by the teachers and students (Rundel & Salemink, 2021), and should thus organize relevant training for the teachers (ChanLin et al., 2016). However, previous studies have shown that schools do not often provide such training (Ishak et al., 2022); therefore, teachers may need to attend training offered by the government or higher education institutions, which may not be relevant to the actual use of technology in their schools (Zagouras et al., 2022). When teaching their classes, in most cases teachers need to use their own internet data plan and technological devices, such as computers and smartphones (Ishak et al., 2022). Teachers also need to design teaching plans to accommodate technology-assisted learning activities. Finally, students – as the primary beneficiaries of technology integration – need devices, internet access and self-directed learning skills (Lembani et al., 2023). The different roles played by each of these three education stakeholders create problems which affect technology integration in different ways. Therefore, the challenges of technology integration, as well as the proposed solutions, are addressed separately for schools, teachers and students in this review.

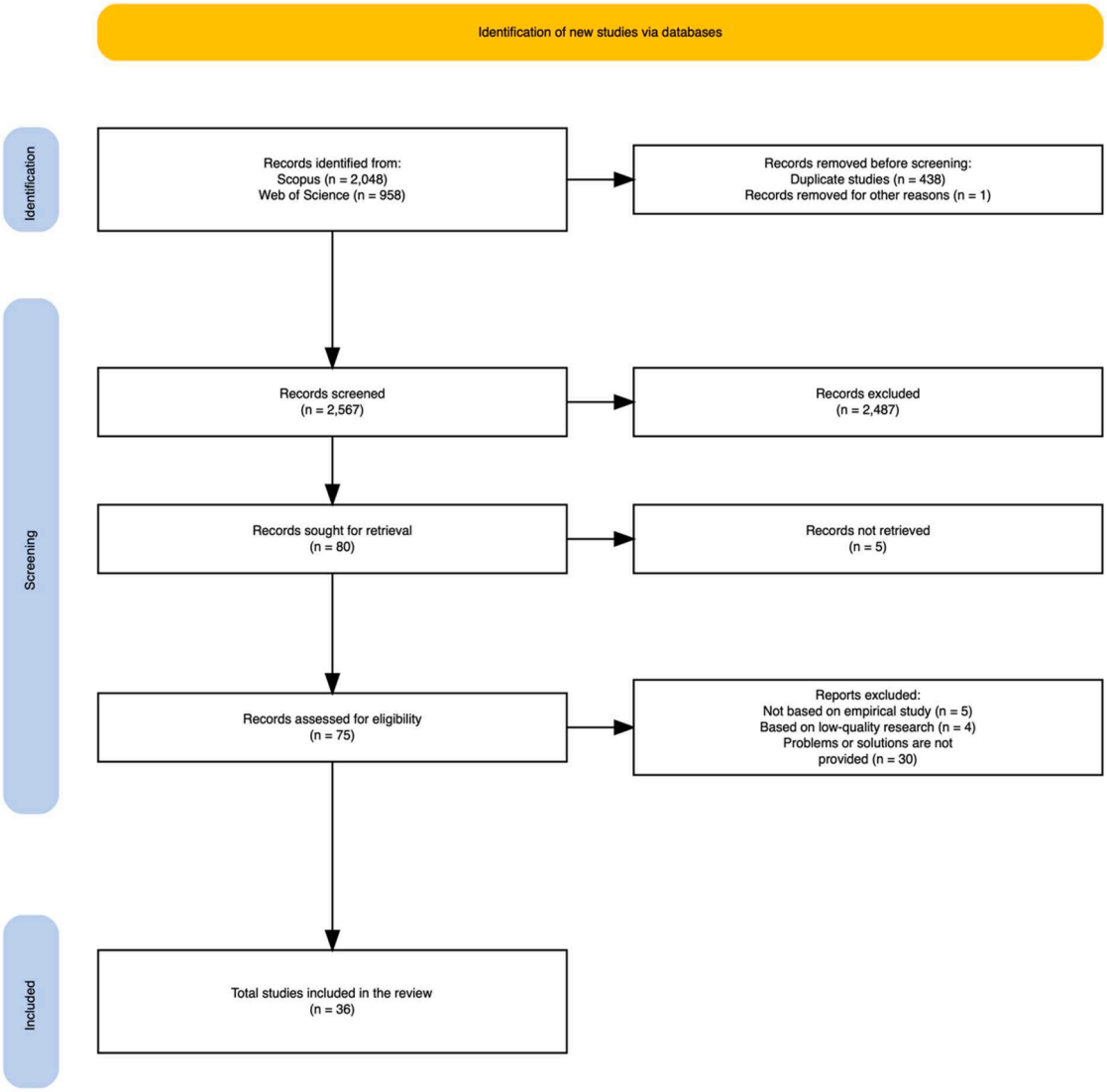

Fig. 1. Study selection flow diagram (a model of PRISMA 2020).

2. The problem statement

The digital divide between urban and rural schools has become a primary concern for practitioners, policymakers, and researchers. For this reason, reviews have been conducted on the use of technology to promote collaboration and virtual learning in New Zealand's rural schools (Whalley & Barbour, 2020) and the effects of equitable access to technology on students' college and career readiness (Mulholland, 2020). This review found that equitable access to the internet was the main concern in rural areas. In addition, Ghimire (2022) reviewed the literature to determine the challenges and opportunities presented by blended learning in rural and remote schools. The study showed that blended learning was preferred over full online learning, and that rural schoolteachers can collaborate with urban schoolteachers who may be more familiar with blended learning. Furthermore, Carrete-Marin and Domingo-Penafiel (2021) summarized how teachers create and share digital resources in rural schools, and emphasized that digital materials need to be suitable for online learning and rural school conditions. Finally, Samane-Cutipa et al. (2022) analysed previous studies on digital gaps, which influenced online learning among students in rural schools. They found that rural school students are less digitally literate than their urban counterparts, while access to technology and the internet is also limited. However, these reviews did not focus on the proposed solutions for technology integration in rural schools, concentrating rather on the challenges.

While it is essential to explore the difficulties that practitioners experience when integrating technology in rural schools, it is also important to examine how these challenges can be addressed and what should be done to overcome them. In addition, the proposed solutions should be intended for use in rural schools because students and teachers have limited access to resources in these contexts in comparison with their rural counterparts. For example, teachers in Zimbabwe claimed that they could not use technology in teaching as they had expected because they did not have reliable internet (Walker et al., 2022). In Pakistan, professional development could not change teachers' classroom practice in rural schools because the program did not consider the school context (Nawab & Bissaker, 2021). In this case, Vaughn and de Beer (2020) state that the "one-size-fits-all" model rarely applies to the integration of technology in rural schools. For this reason, the present study systematically reviews the latest research on technology integration in rural schools to identify both the challenges and the proposed solutions, so that good practices for technology integration can be identified for rural schools. As the use of technology in education has been evolving rapidly since 2014, when new policies in many countries in Southeast Asia (Suhendra et al., 2020), East Asia (Luo et al., 2022), West Asia (Alqahtani, 2018), South America (Del Barrio & Martins, 2017), and East Africa (Tandika & Ndijuye, 2020) explicitly regulated technology integration in education, this review focuses on articles published between 2014 and 2023. The review period also acknowledges the profound impact of the COVID-19 pandemic on education in 2019–2022, which led to an explosion of studies on the integration of technology in education. The review aims to answer the following research questions:

1. What challenges of technology integration in rural schools can be identified in the reviewed studies?
2. What proposed solutions for the challenges of technology integration in rural schools can be identified in the reviewed studies?

By addressing these questions in this review, we intend to identify what should be done to promote good practices for technology integration in rural schools.

3. Method

In conducting this review, we used the latest version of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA 2020) established by Page et al. (2021), as illustrated in Fig. 1. To ensure that the review used quality sources, the literature was acquired from two major databases: Web of Science (WoS) and Scopus. Keywords were used to include as many results as possible. During the review process, articles irrelevant to the review objectives were excluded. To achieve this, we used five search layers, as presented in Table 1.

The main keyword "technology" was used with its variations to ensure that all relevant articles and conference papers were included. The second layer was the context of the study, representing technology integration in an under-resourced context, and the third layer was aimed at including only those results related to teaching or learning in schools. Finally, the fifth layer excluded literature involving research at the higher education level. The wildcard "*" was used to include words with various forms, such as "school*" to include "schools" and "schooling." The titles, abstracts, and keywords of published articles were searched for the keywords.

Table 1
Keywords for literature search.

Layer	Operator	Keywords	Number of articles
1	–	"technology" OR "ICT" OR "online" OR "virtual" OR "distan*" OR "computer*"	Scopus = 2031
2	AND	"rural" OR "under resource*" OR "remote" OR "underprivilege*"	WoS = 949
3	AND	"learning" OR "teaching"	Total = 2980
4	AND	"school*"	
5	(AND) NOT	"universit*"	

3.1. Selection of literature

Searches using the keywords presented in Table 1 generated almost 3000 papers, book chapters, and conference papers. These publications were then screened for inclusion by reading their titles and abstracts. The following inclusion criteria were developed as a guideline to select relevant literature to answer the research questions:

1. The literature is an article, book chapter, or conference paper,
2. The literature is based on empirical research, and
3. The literature refers to problems or proposed solutions relating to technology integration in rural primary and secondary schools.

Both qualitative and quantitative studies were considered because Critical Interpretive Synthesis (CIS) uses evidence from both types of study (Depraetere et al., 2021). Any literature that did not fall under the inclusion criteria based on its abstract was excluded. Due to limited research on technology integration in rural schools, we expanded the literature search to include any publications which relate to the reviewed topic in order that no related publications were missed. Therefore, in the initial screening process, we carefully assessed whether the publications met the inclusion criteria. In the process, we screened out many publications that do not relate to the research topic. For example, the keyword "remote" that we used does not always refers to "distant" such as remote areas. We found many cases where the word "remote" in the publication titles or abstract refers to "online" or "through network". As a results, 2487 publications were excluded at this selection stage. The full texts of the selected publications were retrieved using a reference manager through the writers' university subscription. The publications that the reference manager could not retrieve were retrieved manually. Publications were excluded if their full texts could not be accessed. Further selection was performed when reading the full texts to assess the eligibility of the studies. We assessed the quality of the publications using the criteria developed by Nguyen et al. (2023), and identified 25 publications ranked as "high-quality" category, 11 in the "medium-quality" category, and four publications in the "low-quality" category. Low-quality publications were excluded from the review. After filtering the articles using these criteria, 36 articles were included in the review (see Fig. 1); descriptions of the articles selected for the review are presented in the next section.

3.2. An overview of reviewed studies

Most publications from the Scopus and WoS databases included in the review were journal articles (31 or 86 %), and the remainder were conference papers (5 or 14 %). Most of the articles were published between 2020 and 2022 (21 or 58 %), indicating the global pandemic's impact on activities related to the use of technology in education. The details of the articles' publication years are presented in Fig. 2. More than half the publications included in this review were based on research conducted in rural schools in African and Asian countries, with South Africa (17 %) and China (14 %) being the most frequent contexts of the research (see Fig. 3).

In the last ten years, research related to technology integration has been conducted in many disciplines. However, since technology integration can be investigated across disciplines, the largest group of selected articles were not restricted to any specific discipline (13 or 36 %). Some involved mixed disciplines (5 or 14 %), such as investigations of students' achievements in both science and language. There were more publications based on research related to language teaching and learning (7 or 19 %) than any other discipline. Researchers also showed great interest in the use of technology in science teaching (e.g., mathematics and chemistry), with publications relevant to this taking up the remaining 19 % of the reviewed studies. However, technology integration in social sciences other than language teaching and learning was rarely explored.

3.3. Analysis of the reviewed studies

Inductive coding was conducted following the procedures associated with Critical Interpretive Synthesis (CIS) developed by Dixon-Woods et al. (2006). This was done to ensure the trustworthiness of the analysis: these procedures involve quality assessment, transparency in theme development, and detailed reporting. Informed by the literature, preliminary coding was undertaken to establish the categorization of the data into themes; for example, "a lack of ICT devices" and "slow internet connection" were grouped

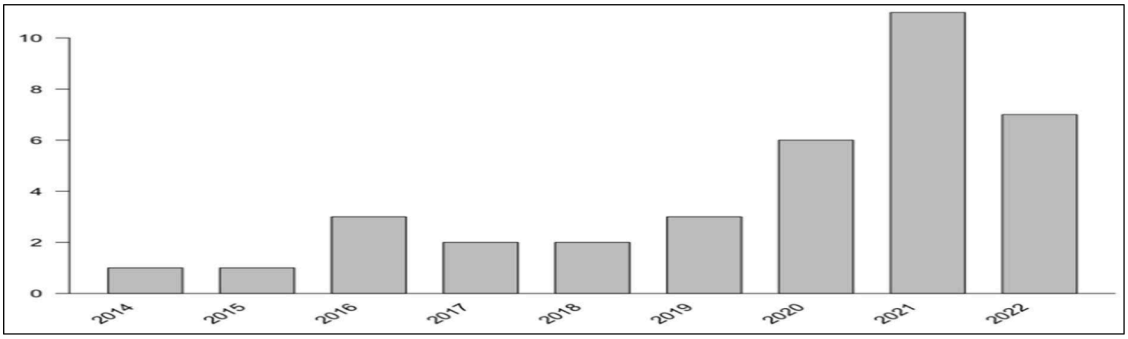

Fig. 2. Publication years of the included literature.

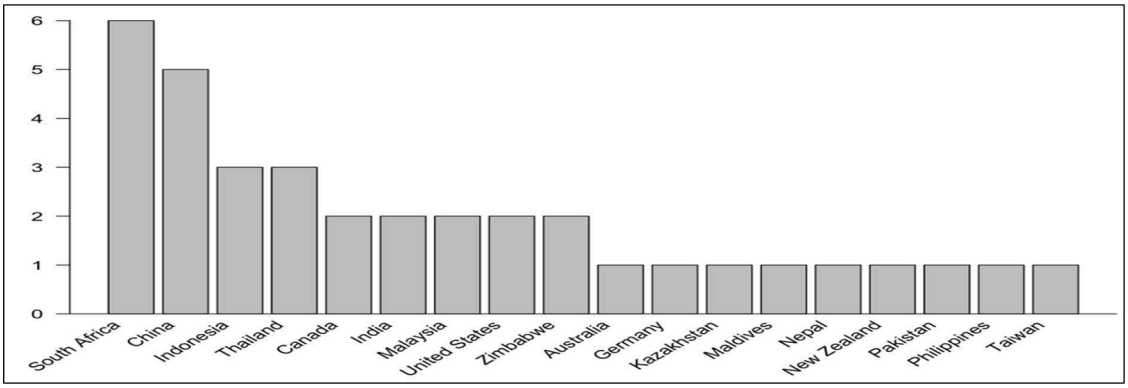

Fig. 3. List of countries.

under "student's problems," and "a lack of training" and "difficulty in assessing students" were grouped under "teacher's problems". Then, these themes were further refined after all studies had been coded. When reading the full texts, the researchers carefully assessed the research questions and research objectives to determine the focus of each publication. When reviewing the studies, research participants (teachers, students, parents, etc.) were also coded, along with the research method and location. The results were coded based on the reviewed studies' research questions or aims. The discussion section of each study was read to confirm the results of the study. Finally, to ensure the reliability of the analysis, the publications were coded by another researcher using the empty codes developed by the previous coder. The level of agreement between the two coders was 98.89 %, which is considered acceptable (Belur et al., 2018). The inter-coder reliability test based on Cohen's kappa was performed in NVIVO, resulting in a K statistic of 0.69. This level is considered "substantial", as interpreted based on Landis and Koch's (1977) table.

The generated themes were categorized into macro, *meso* and micro levels, following the ecological approach adapted from Bronfenbrenner (1979). The ecological perspective emphasizes that technology adoption requires interactions among the individuals within the system (Hammond, 2020). The macro level includes challenges related to policies dealing with teaching and infrastructure at the regional and national levels. Meso level challenges are those at the school level, which occur due to school-level rules, policies, and expectations (Zagami, 2012). Finally, micro-level challenges manifest in classrooms, and involve the interaction between teachers and students as well as the classroom environment (Brown, 1992).

4. Results

In this section, we report the themes identified in the reviewed publications with reference to the research questions of this review. The analysis of 36 studies identified 25 challenges, some of which were presented together with proposed solutions. The identified challenges can be categorized into three levels based on the ecological perspective framework, i.e., the macro level, *meso* level, and micro level. Most of these challenges were reported along with one or more proposed solutions in the reviewed studies, although some were discussed without any clear solutions being proposed.

Table 2
Challenges and proposed solutions for integrating technology at the macro level.

No	Challenges	Study	Proposed solution	Study
1	Lack of funding	Arreerard (2022); Barbour et al. (2016); Luo et al. (2022); Rahim et al. (2020); Jerry and Yunus (2021)	1. Financial support from government 2. Non-government sponsorship	1. Que (2021); Tsimba et al. (2020) 2. Mihai and Nieuwenhuis (2015); Que (2021); Tsimba et al. (2020)
2	Lack of qualified teachers	Arreerard (2022); Luo et al. (2022)	1. Professional development 2. Teacher collaboration	1. Arreerard (2022) 2. Luo et al. (2022)
3	No internet connection at school	Arreerard (2022)	1. Intervention from the government to provide technological infrastructure. 2. Using a non-internet sharing service such as Wi-Fi or Bluetooth.	1. Arreerard (2022) 2. Tsimba et al. (2020)
4	Slow or unstable internet connection	Fikuree et al. (2021); Kusuma (2022); Martin (2021); Mihai (2017); Mudra (2018); Singh et al. (2021)	Teachers to use applications requiring low internet bandwidth such as WhatsApp.	Kusuma (2022)
5	Lack of collaboration with other schools	Barbour et al. (2016); Kerimbayev et al. (2016)		
6	Frequent blackouts	Singh et al. (2021)		

4.1. Challenges and proposed solutions at the macro level

The challenges at the macro level are related to conditions beyond the school level, over which schools have little control. For example, many schools do not have adequate government funding to support technology integration; therefore, seven studies reported that schools did not have enough computers to support digital learning (e.g. Arreerard, 2022; Jerry & Yunus, 2021; Tsimba et al., 2020). In addition, teachers appointed by the government in rural schools rarely have adequate qualifications for integrating technology into their teaching (Arreerard, 2022; Luo et al., 2022). Furthermore, in many schools in rural areas, only one teacher is available to teach each subject, and the policies of the government or the Department of Education do not facilitate collaboration between teachers across schools (Barbour et al., 2016; Kerimbayev et al., 2016). As a result, teachers may not have opportunities to improve their use of technology in teaching. Another commonly reported challenge of technology integration is that many schools do not have an internet connection (Arreerard, 2022), and when they do, it is slow and unstable (e.g., Martin, 2021; Mihai, 2017; Mudra, 2018). The above challenges are more evident in developing countries such as Thailand (Arreerard, 2022), Pakistan (Rahim et al., 2020), but some funding for the technology initiatives was provided to address these challenges by governments in developed countries such as New Zealand (Barbour et al., 2016) (Table 2).

The literature suggests solutions for some challenges at the macro level. To address the challenge of a lack of funding in rural schools, the literature recommends that schools seek additional financial support, in addition to their annual government-allocated budget, from both governmental and non-governmental institutions (e.g., Mihai & Nieuwenhuis, 2015; Que, 2021; Tsimba et al., 2020). Furthermore, the reviewed studies suggest implementing professional development programs (Arreerard, 2022) and teacher collaboration (Luo et al., 2022) to address the lack of qualified, well-trained teachers in rural schools. Finally, it is also recommended for schools to request government funding to provide internet infrastructure (Arreerard, 2022), or for schools to use non-internet sharing services such as local Wi-Fi sharing and Bluetooth (Tsimba et al., 2020). If their internet connection is slow or unstable, which is common in rural schools, teachers are recommended to use applications or websites that do not require high internet bandwidth (Kusuma, 2022). However, solutions to the other two challenges – the lack of collaboration across different schools and problems with the supply of electricity – are not found in the literature. Most of the macro contextual challenges can only be addressed by the investment of substantial resources. It seems that researchers are unsure of whether they can secure these resources to ensure the equitable integration of technology into education in rural schools.

4.2. Challenges and proposed solutions at the meso level

The challenges at the *meso* level, along with the proposed solutions identified in the literature, are presented in Table 3. The table shows that one of the challenges concerns school principals who do not have a vision for technology integration (Owen et al., 2020; Rahim et al., 2020; Wang et al., 2022). As a result, they lack commitment to and knowledge of technology integration in rural schools. Another challenge is the lack of technological devices in schools, which is related to the lack of funding at the macro level (see Table 3). Seven studies reported that teachers could not use technology in rural schools because the schools did not have computers, computer laboratories, or other technological devices (e.g., Fan et al., 2020; Jerry & Yunus, 2021; Kerimbayev et al., 2016). However, this lack of technological devices is rarely reported in rural schools in developed countries such as Australia (Lock & Forlin, 2006) and New Zealand (Barbour et al., 2016). One study reported that even when technology devices are available, many schools in developing countries do not have the technical support staff necessary to solve problems with these devices (Rahim et al., 2020). In addition, teachers said they need technical support staff who understand the pedagogical use of technology and can provide help beyond solving

Table 3
Challenges and proposed solutions for integrating technology at the *meso* level.

No	Challenges	Study	Proposed solution	Study
1	Ill-prepared school principals	Owen et al. (2020); Rahim et al. (2020); Wang et al. (2022)	1. Training for school principals on technology integration and policy. development 2. Previous experience in technology integration.	1. Owen et al. (2020); Rahim et al. (2020); Wang et al. (2022) 2. Slaughter et al. (2019)
2	Lack of technology devices in schools	Arreerard (2022); Barbour et al. (2016); Fan et al. (2020); Jerry and Yunus (2021); Kerimbayev et al. (2016); Rahim et al. (2020); Tsimba et al. (2020)	Intervention from the government to provide technological infrastructure.	Barbour et al. (2016); Jerry and Yunus (2021); Tsimba et al. (2020)
3	Lack of technical support staff in schools	Jerry and Yunus (2021); Rahim et al. (2020); Rundel and Salemink (2021)	Provision of trained IT staff by government.	Rahim et al. (2020)
4	Lack of educational technology IT support for teachers	Jerry and Yunus (2021); Rundel and Salemink (2021)	1. ICT technical staff 2. Educational technology staff.	1. Barbour (2022); Martin (2021); Wang et al. (2021) 2. Rana et al. (2022); Slaughter et al. (2019)
5	Lack of technical support for students at home	Fikuree et al. (2021)	Advanced ICT training be given to all school staff.	Rundel and Salemink (2021)
6	Lack of maintenance of technology devices	Arreerard (2022); Luo et al. (2022)		
7	Lack of physical teaching space	Fikuree et al. (2021)		

technical issues with computers or technology devices (Jerry & Yunus, 2021; Rundel & Salemink, 2021). The literature also reveals that when students need to complete assignments involving technology at home, they do not have access to technical support when they encounter technical issues (Fikuree et al., 2021). The other challenges include a lack of maintenance of technological devices in schools (Arreerard, 2022; Luo et al., 2022) and a lack of physical space for teachers to use when they need to teach an online class in countries such as Maldives (Fikuree et al., 2021).

To address the issues with school leadership and principals, the literature suggests that school principals in rural schools be given professional development training covering technology integration and policy development (Rahim et al., 2020; Wang et al., 2022). It is also suggested that education departments appoint principals with experience in technology integration programs in urban or rural areas. To address the lack of technological devices in rural schools, the literature advocates government intervention to provide technological infrastructure (Barbour et al., 2016; Jerry & Yunus, 2021; Tsimba et al., 2020). The literature also suggests that the government provide trained IT staff for schools which have technological devices (Rahim et al., 2020). In addition, the literature recommends that schools provide staff specializing in educational technology to help teachers overcome technological problems when teaching (e.g., Rana et al., 2022; Slaughter et al., 2019; Wang et al., 2021). To ensure students have access to technical support when completing their homework, Rundel and Salemink (2021) suggest that advanced ICT training be given to all rural school teachers so that they can provide technical support to their students.

4.3. Challenges and proposed solutions at the micro level

The challenges of technology integration at the micro level are summarized in Table 4 (teacher-related challenges) and Table 5 (student-related challenges). Table 4 includes the challenges that teachers experience due to their level of knowledge, their classroom environment, and their students. Previous studies have shown that teachers experience many problems using technology for teaching at this level. The predominant problems are a lack of technological literacy (Molise & Dube, 2020; Owen et al., 2020) and limited knowledge of how multimedia resources can be used to support their teaching (Herselman et al., 2019; Luo et al., 2022; Poonpon, 2021). Teachers' challenge with technology literacy or pedagogical knowledge was found in most countries such as China, Indonesia, Malaysia, Thailand, South Africa and the United States (Howell, 2018). Studies have also shown that teachers who are technologically literate do not have adequate knowledge of the pedagogical use of technology (Owen et al., 2020; Rana et al., 2022). Therefore, they cannot accurately assess their students' online learning achievement using technology (Luo et al., 2022; Singh et al., 2021). In

Table 4
Teacher-related challenges and proposed solutions for integrating technology at the micro level.

No	Challenges	Study	Proposed solution	Study
1	Lack of technology literacy among teachers	Arreerard (2022); Jerry and Yunus (2021); Molise and Dube (2020); Owen et al. (2020)	1. Comprehensive training and supervision. 2. Consulting with colleagues and technicians. 3. ICT training for teachers. 4. Professional development for teachers. 5. Independent learning. 6. Sharing sessions among teachers. 7. Using generic software.	1. Fikuree et al. (2021); Molise and Dube (2020) 2. Poonpon (2021) 3. Fan et al. (2020); Fikuree et al. (2021); Howell (2018) 4. Owen et al. (2020) 5. Poonpon (2021) 6. Que (2021) 7. Howell (2018); Kai and Hua (2021); Molise and Dube (2020); Pimvichai et al. (2014); Pindiprolu and Marks (2020)
2	Teacher inadequate knowledge of technology pedagogical use	Herselman et al. (2019); Howell (2018); Luo et al. (2022); Owen et al. (2020); Poonpon (2021); Rana et al. (2022)	1. Comprehensive ICT training including pedagogical use of ICT. 2. Professional development. 3. Professional development on ICT integration in classroom. 4. Training on using relevant ICT platforms. 8. Curriculum update for pre-service teacher training program.	1. Herselman et al. (2019) 2. Howell (2018) 3. Owen et al. (2020) 4. Arreerard (2022); ChanLin et al. (2016); Fikuree et al. (2021); Herselman et al. (2019); Martin (2021) 8. Poonpon (2021)
3	Lack of technology devices for teachers' personal use	Fikuree et al. (2021); Martin (2021); Owen et al. (2020); Singh et al. (2021); Wang et al. (2022)	Using alternative platforms.	Srinivasan et al. (2021)
4	Lack of focus when teaching multiple classrooms from multiple schools	Luo et al. (2022)	Involving in-school teachers in instructional activities.	Luo et al. (2022)
5	Overwhelming workload	Jerry and Yunus (2021); Mihai and Nieuwenhuis (2015); Que (2021); Wang et al. (2022)	Collaboration by allocating teaching preparation work and using available digital materials.	Poonpon (2021)
6	Negative attitude	Molise and Dube (2020)		
7	Teachers' inadequate knowledge of online learning assessment	Luo et al. (2022); Singh et al. (2021).		

Table 5
Student-related challenges and possible solutions at the micro level.

No	Challenges	Study	Proposed solution	Study
1	Lack of compatible devices for students	Fikuree et al. (2021); Kusuma (2022); Singh et al. (2021); Wang et al. (2021)	1. Teachers to use alternative platforms that can be accessed via any type of internet-access device. 2. Sharing devices with other students. 3. Using smartphones to replace computers.	1. Srinivasan et al. (2021) 2. Srinivasan et al. (2021) 3. Ogegbo and Ramnarain (2022); Owen et al. (2020); Tsimba et al. (2020)
2	Data plan unaffordable for students	Rundel and Salemink (2021); Singh et al. (2021)	Teachers to use applications using low bandwidth such as WhatsApp.	Kusuma (2022)
3	Students' limited technology literacy	Srinivasan et al. (2021)	1. Training on ICT and digital learning. 2. Using ICT tools which students are already familiar with.	1. Fikuree et al. (2021); Meyer et al. (2017) 2. Muzurura et al. (2021)
4	Lack of study space for students	Srinivasan et al. (2021)	Providing a library and learning centre in every village.	Srinivasan et al. (2021)
5	Student difficulty in interaction	Srinivasan et al. (2021)	TPACK training for teachers.	Li et al. (2019)

addition, teachers also experience many technical difficulties. For example, they frequently report problems stemming from the limitations of technological devices in developing countries such as China (Fikuree et al., 2021), India (Singh et al., 2021), Indonesia (Owen et al., 2020), and even developed countries such as Canada (Martin, 2021). When teachers teach multiple classes from other schools using synchronous video conferences, they can quickly lose focus, as the case in China (Luo et al., 2022). The problems escalate because teachers do not have enough time to prepare materials for technology-assisted classes (Que, 2021). With all these requirements, teachers state that using technology has increased their workload (Mihai & Nieuwenhuis, 2015). As a result, rural school teachers' attitude towards technology integration is not always positive (Molise & Dube, 2020).

To solve technological literacy issues, the results of the systematic literature review suggest that teachers in rural schools should attend ICT training (Fan et al., 2020; Howell, 2018), and seek supervision and peer support (e.g. Fikuree et al., 2021; Molise & Dube, 2020; Poonpon, 2021). Motivated teachers are also advised to learn to use technology independently or to employ simple ICT tools when teaching (Poonpon, 2021). In addition, nine studies recommended comprehensive ICT training or professional development covering technology, pedagogy and content knowledge ('TPACK') (e.g. Herselman et al., 2019; Howell, 2018; Owen et al., 2020). One study suggested that pre-service teacher training institutions in Thailand update their curriculum to offer courses on the pedagogical use of ICT (Poonpon, 2021). Another solution is for teachers to use generic computer software, such as Microsoft Office, that they are already familiar with (Howell, 2018; Kai & Hua, 2021; Pimvichai et al., 2014). Although this software is intended for general use, it can be utilized for teaching purposes, especially in rural schools. To address the lack of technological devices for teachers' personal use in rural schools in India, Srinivasan et al. (2021) suggest using alternative ICT platforms that are compatible with the devices teachers and their students already have to solve this problem. To minimize workloads, a study by Poonpon (2021) suggests that teachers collaborate to allocate work among themselves during teaching preparation and the design of digital materials. In one case, due to a lack of qualified teachers in rural schools in China some teachers were required to teach more than one class online: a live feed from one in-person class was transmitted to other classes simultaneously, so that they could interact with students in all the classes. As a result, the teachers quickly lost their focus. To help these teachers retain their focus, the literature suggests that they design learning activities which involve in-school teachers in order to distribute the work evenly (Luo et al., 2022). However, the literature does not address issues relating to negative attitudes or a lack of assessment skills among teachers in rural schools.

In addition to the challenges involving teachers and their interaction with their knowledge and the school environment, the challenges of technology integration at the micro level also involve students. These challenges and their proposed solutions are presented in Table 5.

As summarized in Table 5, four studies report a lack of compatible devices and unaffordable data costs among rural school students (e.g., Rundel & Salemink, 2021; Singh et al., 2021; Wang et al., 2021). These challenges were reported in studies conducted in different countries such as China, India, Indonesia, Maldives, and even Germany. Another study reporting on research in India revealed that rural school students have problems with limited technological literacy, a lack of supportive study spaces, and difficulty interacting with teachers (Srinivasan et al., 2021). One study found that students lose their motivation to learn as a result of these challenges in the use of technology (Kusuma, 2022). Finally, another study reports teachers' concerns about internet addiction and cyberbullying (Rundel & Salemink, 2021). In summary, these studies show that the student-related challenges of technology integration are complex, and thus need to be anticipated before any technology integration initiative begins.

The literature provides solutions for the challenges experienced by students. For students' challenges related to a lack of compatible technological devices, studies suggest that teachers in rural schools use alternative platforms which can be accessed using devices that the students already have, and advise students to share devices with family members and classmates (Owen et al., 2020; Srinivasan et al., 2021; Tsimba et al., 2020). In addition, it is recommended that teachers use ICT tools which require only a low internet bandwidth to make internet connections more affordable, because internet data is costly for many rural school students in some developing countries such as Indonesia (Kusuma, 2022). Furthermore, the challenges of technology literacy can be solved by training rural school students in ICT and digital learning before implementing ICT initiatives (Fikuree et al., 2021); Meyer et al. (2017). Alternatively, teachers could use technological tools that their students are already familiar with (Muzurura et al., 2021). A study by Srinivasan et al. (2021) suggests that the government establish libraries and learning centres in rural areas to provide study spaces

Table 6
Good practices for technology integration in rural schools.

Levels	Good practices	Studies
Macro level	*Technology devices* Financial support needs to be sought from the government and non-government institutions to procure computers and other supporting technological devices.	Arreerard (2022); Barbour et al. (2016); Fan et al. (2020); Jerry and Yunus (2021); Kerimbayev et al. (2016); Mihai and Nieuwenhuis (2015); Que (2021); Rahim et al. (2020); Tsimba et al. (2020)
	School principals Government needs to provide school principals with professional development training related to technology integration.	Owen et al. (2020); Rahim et al. (2020); Wang et al. (2022)
	Teachers Professional development training needs to be provided to teachers to improve their ICT skills and knowledge of the pedagogical applications of ICT.	Arreerard (2022); ChanLin et al. (2016); Fan et al. (2020); Fikuree et al. (2021); Herselman et al. (2019); Howell (2018); Luo et al. (2022); Martin (2021); Molise and Dube (2020); Owen et al. (2020)
Meso level	*Students* Students need training on how to use the technological devices that will be used by their teachers.	Fikuree et al. (2021); Meyer et al. (2017)
	Technical support Schools need to provide technical support staff for teachers and students.	Barbour (2022); Martin (2021); Rahim et al. (2020); Rundel and Salemink (2021); Wang et al. (2021)
	Internet connection Internet connection should be provided in schools through Wi-Fi or internet cable.	Arreerard (2022); Tsimba et al. (2020)
	Teacher collaboration Teachers should collaborate so that they can allocate teaching preparation work and the use of available digital materials.	Luo et al. (2022); Poonpon (2021)
Micro level	*Teaching methods* Teaching methods need to consider the use of limited technology devices and devices which do not require a high-speed internet connection	Owen et al. (2020); Srinivasan et al. (2021); Tsimba et al. (2020)
	Teaching tools Teachers should use learning platforms or media which are compatible with students' technological devices and their internet speeds.	Kusuma (2022); Srinivasan et al. (2021)
	Assessment tools Teachers should use applications that do not require an internet connection or require only low internet bandwidth.	Arreerard (2022); Kusuma (2022); Tsimba et al. (2020)

where students can study online. In addition, the challenges of student-teacher interaction in online classes are related to teachers' pedagogical knowledge with regard to the use of technology; thus, Li et al. (2019) suggest that the government offer TPACK training for teachers, focusing on classroom management in online learning. To address teachers' concerns about internet addiction and cyberbullying as experienced by students in German rural schools, it is recommended that schools establish a policy for mobile device use which includes strict monitoring (Tsimba et al., 2020). Finally, to deal with students' lack of learning motivation, it is suggested that teachers use a learning platform which their students are already familiar with to minimize the challenges experienced by the students (Muzurura et al., 2021).

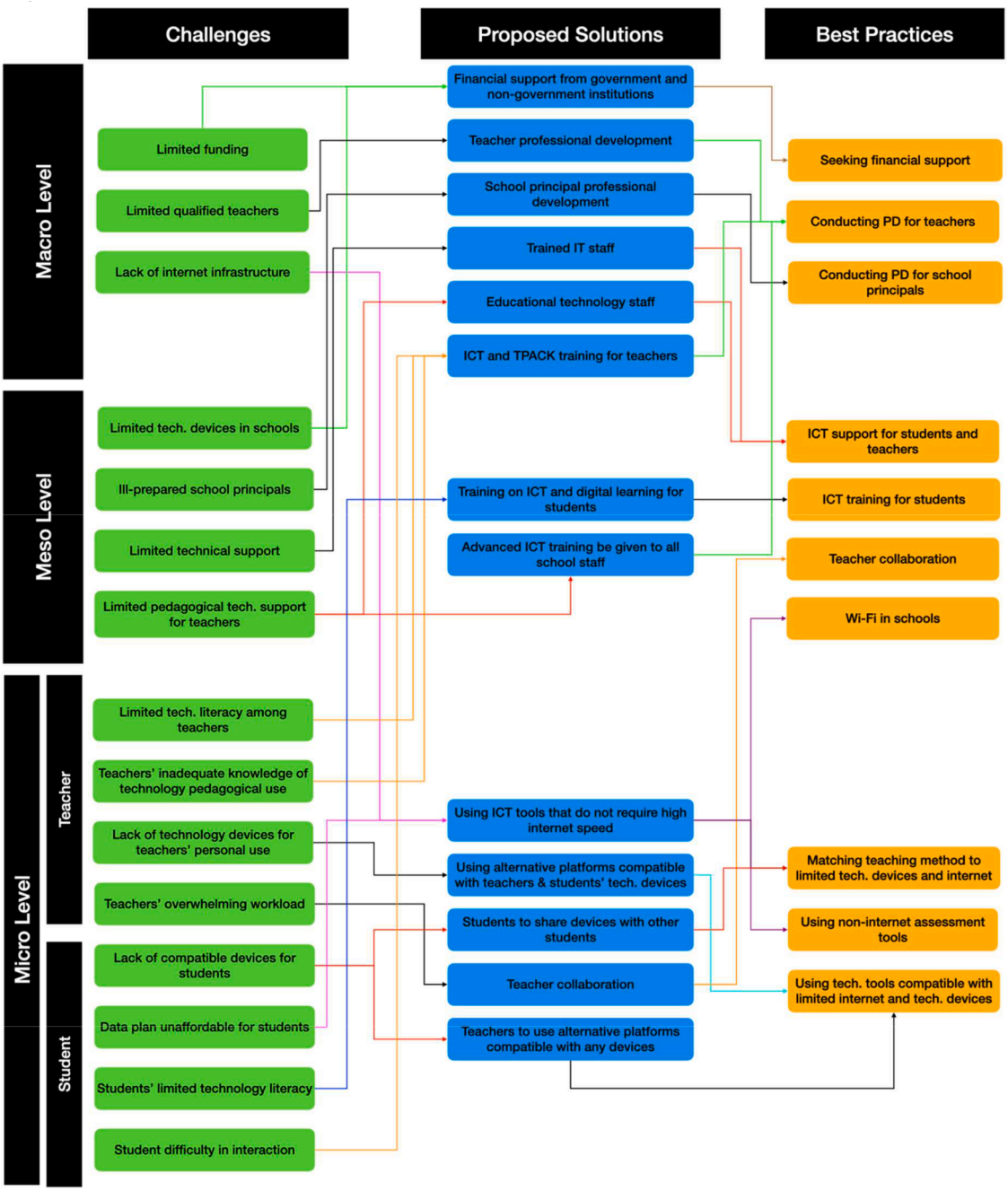

Fig. 4. Diagram of the challenges, proposed solutions, and good practices of technology integration in rural or under resourced schools.

4.4. Promoting good practices for technology integration in rural schools

The suggested solutions for the challenges of technology integration in rural schools reveal good practices for the promotion and sustainment of technology integration in an under-resourced context. These good practices are summarized in Table 6.

Reviewing the literature revealed the good practices for technology integration in rural schools. Table 6 shows that some of the good practices involve institutions beyond the school level, e.g., government institutions such as the Ministry of Education. These institutions are responsible for providing schools with adequate financial support to procure technological devices, as recommended for rural schools in countries such as China, Indonesia, Malaysia, Thailand, Zimbabwe, and New Zealand (Fan et al., 2020; Kerimbayev et al., 2016; Mihai & Nieuwenhuis, 2015). Schools do not usually have an adequate budget to purchase technological devices, and thus government intervention is necessary (Rahim et al., 2020). In addition, the Ministry of Education also needs to provide professional development opportunities for both school principals and teachers. Teachers should be given professional development training on the process of technology integration (Owen et al., 2020; Rahim et al., 2020; Wang et al., 2022) and on how to use technology to enhance their teaching activities (ChanLin et al., 2016; Howell, 2018; Molise & Dube, 2020). Given the right infrastructure, qualified school principals and prepared teachers, technology integration in rural schools is likely to be successful.

Furthermore, at the school level students need to be given preparatory training before technology can be used because, according to Srinivasan et al. (2021), many students in rural areas in India are not technologically literate. This training should be specific to the technological tools or platforms that will be used in their classes (Fikuree et al., 2021; Meyer et al., 2017). Additionally, schools should provide technical support staff to solve technical problems when these occur, because students and teachers in the school context might not have the necessary troubleshooting skills (Barbour, 2022; Martin, 2021; Wang et al., 2021). In addition, schools need to provide an internet connection because rural areas do not always have reliable cellular internet connections, as observed in Indonesia (Mudra, 2018), and many rural school students cannot afford internet data plans even in developed countries such as Germany (Rundel & Salemink, 2021; Singh et al., 2021). Finally, teachers should collaborate to allocate work when preparing materials, thereby minimizing the workload (Poonpon, 2021).

At the micro level, teachers teaching in rural areas need to adjust their teaching methods by considering the infrastructural and resource-related limitations which affect rural schools. Firstly, teachers must choose learning activities which are appropriate to the limitations of their technological devices (Owen et al., 2020; Tsimba et al., 2020). For example, teachers can arrange group work projects in which students can share their devices. Secondly, learning assessments should be performed as smoothly as possible, and teachers thus need to consider their students' internet connections (Srinivasan et al., 2021). The best practice is that teachers use applications that do not require an internet connection, or those that do not demand high internet bandwidth (Arreerard, 2022; Kusuma, 2022; Tsimba et al., 2020).

5. Conclusion

This systematic review identifies the challenges related to the integration of technology into learning and teaching in rural schools and suggests solutions and good practices for technology integration in the context of rural schools (see Fig. 4). Seventy-two per cent of the reviewed articles identified 25 challenges of technology integration in rural schools, which were categorized as macro level (30 %), *meso* level (33 %), and micro level (53 %) challenges. In addition, 89 % of the reviewed studies proposed solutions to these challenges. Based on these results, nine good practices were identified from discussions in 67 % of the reviewed publications. These results can be used as a basis for devising a sustainable plan for integrating technology in the context of under-resourced schools by considering the possible challenges, how they should be addressed, and what preparations must be taken before the technology integration initiative can be started.

The reviewed studies show that technology integration in rural schools is complex because many of the challenges are at the macro level. To put this into perspective, students in rural areas rarely have technological devices suitable for digital learning, especially in developing countries (Singh et al., 2021). Schools therefore need adequate infrastructure to support the integration of technology. However, schools in rural areas rarely have access to sufficient budgets, and thus have to rely on financial support from the government, which is extremely scarce. When infrastructure is inadequate, teachers are not motivated to participate in technology-related professional development (Bariu & Chun, 2022). Teachers also tend to seek professional development tailored to their needs (Elmaadaway & Abouelenein, 2022). In addition, professional development training is rarely conducted in rural areas, and teachers are not financially supported by their schools to participate in professional development activities in urban areas (Yang, 2021). As a result, very few teachers in rural areas participate in professional development activities (Budianto et al., 2023). These multilayered challenges explain why successful technology integration is so rare in rural schools. In addition, research on teachers' professional development in this context of under-resourced schools is limited.

We have identified that professional development for teachers is one of the solutions for technology integration in rural schools proposed in the literature based on research in developing and developed countries. Professional development activities are intended to improve teachers' knowledge and their classroom instruction (Chai, 2019; Escribano et al., 2020; Mukeredzi, 2014) as factors in student learning outcomes. However, none of the reviewed studies investigated how professional development is linked directly to classroom practices. Further, studies on the effect of professional development on teachers' knowledge were restricted to teachers' reported knowledge, without utilizing reliable pre-test and post-test surveys. Therefore, it is unclear what kind of professional development would be most valuable in rural schools. In addition, the reviewed studies identified teachers' lack of knowledge in relation to technology-assisted student assessment. For example, teachers reported that they could not accurately assess students' learning achievement online during the COVID-19 pandemic (Singh et al., 2021). However, none of the studies offer a solution to this

challenge.

Regardless of these complexities, the results of our systematic review have significant implications for efforts to integrate technology into education in rural schools or under-resourced schools. At the macro level, good practices relate to access to technological devices and professional development for school principals and teachers. Satisfying these technology integration requirements may require government policy and funding support for under-resourced schools. Rural schools need the government's support for technology device procurement and professional development so that they can have a solid foundation to launch and sustain technology integration initiatives .

At the *meso* level, good practices include training in the use of technology for students, technical support, and internet access. According to the literature, these are the three factors that need to be prepared before technology can be brought into classrooms. However, there is a lack of research on how they affect classroom practices, students' perceptions, or learning outcomes. Further research is necessary to determine how these three factors can be manipulated to achieve maximum results from technology integration.

Finally, the majority of the reviewed literature focused on the micro level. Good practices at this level involve teaching methods, technological tools or platforms, and assessments. The reviewed studies emphasize the need to adjust these three factors to reflect the reduced availability of technological devices and internet access in rural schools. Therefore, professional development is recommended as a way to provide rural schoolteachers with the knowledge they need to select technological platforms and teaching methods which meet rural school conditions. In addition, educational technology industries should design technology platforms specified for rural schools. These platforms would need to be user-friendly, because rural school students may not already be familiar with educational technology. They should also be compatible with any operating system, because rural school students have a limited range of technological devices. Finally, the platforms should enable offline access, allowing the learning materials to be downloaded when the device is connected to the internet. With this feature, students will be able to complete their assignments and learning activities without an internet connection, with students' work being sent to the server when the internet becomes available. This feature is essential, given that internet access is often unreliable in rural areas.

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CRediT authorship contribution statement

Faisal Mustafa: Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. **Hoa Thi Mai Nguyen:** Conceptualization, Formal analysis, Methodology, Supervision, Writing – review & editing. **Xuesong (Andy) Gao:** Conceptualization, Methodology, Supervision, Writing – review & editing.

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