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ORIGINAL

Digital empowerment of rural teachers: towards an innovative pedagogy in the 21st century

Empoderamiento digital de docentes rurales: hacia una pedagogía innovadora en el siglo XXI

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ABSTRACT

This study focuses on the digital empowerment of teachers in rural areas of Colombia, a region where less than 40 % of schools have broadband internet access. In the context of the COVID-19 pandemic, which has significantly exacerbated the digital divide, we propose the innovative Digital Empowerment Model for Rural Teachers (MCDDR). This model is based on a rigorous systematic literature review that identifies and synthesizes successful educational practices adapted to similar contexts. The MCDDR is specially designed to be flexible and adaptable to local needs, seeking to promote a profound pedagogical transformation through the effective integration of information and communication technologies (ICT). Based on the successful practices identified, the model has a strong potential to revolutionize education in rural Colombia. Its strategic implementation is expected not only to effectively address the educational digital divide, but also to substantially improve the quality and equity of education in these areas. By anticipating the positive impacts of the MCDDR, the study underscores the urgent need for policies that support the implementation of innovative digital solutions in rural education, which could guarantee equitable access to educational opportunities in the contemporary digital era.

Keywords: Digital Empowerment; Rural Teachers; Digital Competencies; Educational Digital Divide; Digital Training Model for Rural Teachers (MCDDR).

RESUMEN

Este estudio se centra en el empoderamiento digital de los docentes en áreas rurales de Colombia, una región donde menos del 40 % de las escuelas disponen de acceso a internet de banda ancha. En el contexto de la pandemia de COVID-19, que ha exacerbado significativamente la brecha digital, proponemos el innovador Modelo de Capacitación Digital para Docentes Rurales (MCDDR). Este modelo se basa en una rigurosa revisión sistemática de la literatura que identifica y sintetiza prácticas educativas exitosas adaptadas a contextos similares. El MCDDR está especialmente diseñado para ser flexible y adaptable a las necesidades locales, buscando promover una transformación pedagógica profunda mediante la integración efectiva de las tecnologías de la información y la comunicación (TIC). Basado en las prácticas exitosas identificadas, el modelo presenta un fuerte potencial para revolucionar la educación en las zonas rurales colombianas. Se espera que su implementación estratégica no solo aborde la brecha digital educativa de manera efectiva, sino que también mejore sustancialmente la calidad y la equidad de la educación en estas áreas. Al anticipar los impactos positivos del MCDDR, el estudio subraya la necesidad urgente de políticas que apoyen la implementación de soluciones digitales innovadoras en educación rural, lo que podría garantizar un acceso equitativo a oportunidades educativas en la era digital contemporánea.

Palabras clave: Empoderamiento Digital; Docentes Rurales; Competencias Digitales; Brecha Digital Educativa; Modelo de Capacitación Digital para Docentes Rurales (MCDDR).

INTRODUCTION

Digital transformation and the evolution of educational methods are fundamental in the 21st century, with teacher training in digital skills crucial to overcoming current challenges. We face a marked vulnerability in rural areas: less than 40 % of rural schools globally have access to broadband internet,[1] highlighting a significant technological gap in modern education. This study underscores the need to digitally empower rural teachers digitally, countering the trend of teacher training programs that do not include digital skills.

Telecommunications,[1] highlighting a significant technological gap in modern education.

This study underscores the need to digitally empower rural teachers, contrasting with the situation in urban areas, where 70 % of teachers feel confident in their digital skills, compared to only 45 % in rural areas. This contrast reflects not only differences in access to technology but also in the quality and relevance of digital skills training, which currently benefits less than 20 % of educators in rural contexts.[2,3,4]

The COVID-19 pandemic has exacerbated these inequalities, highlighting the critical importance of digital skills for educational continuity. Globally, more than 50 % of the student population was affected by school closures, disproportionately impacting rural communities. In Colombia, the intensive use of social media platforms indicates high internet penetration, but this does not necessarily translate into practical digital skills for teaching.[5]

The digital divide in Colombia and Latin America, exacerbated by the pandemic, disproportionately affects rural teachers, with internet access varying significantly by income, geographic location, and age. While 81 % of people in the highest income quintile had internet access, only 38 % in the lowest quintile did.[3,6] At the same time, the need to improve educators' digital skills has become urgent, driving the accelerated adoption of virtual education.[7]

The urgency of addressing the digital divide in rural areas is even more pronounced today, where digitization is considered an essential infrastructure, as crucial as access to basic services such as electricity and water. This approach is based on research highlighting the importance of active national policies and private sector partnerships to improve Internet quality in rural areas, which are often characterized by low density that discourages commercial investment without government incentives.[8,9] By integrating these considerations into the study, the relevance of developing digital skills that not only balance educational opportunities but also foster these communities' comprehensive economic and social development is emphasized.

This study seeks to design and validate a specific model for teacher training in rural areas, adopting a holistic perspective to integrate digital skills into rural education.[10] This work contributes significantly to education and the development of digital skills in rural areas of Colombia through a comprehensive analysis that covers macro, meso, and micro levels. By identifying particular challenges in implementing digital skills in these contexts, practical solutions that can be adapted to local needs are offered. Adopting flexible educational models and promoting cooperation between different sectors aims to improve both access to technology and teacher training, ensuring that rural educators have the necessary resources to promote high-quality education in the digital age. This collaborative and flexible strategy, together with the implementation of training programs that combine pedagogy with educational technology, sets a crucial precedent for the digital empowerment of rural teachers and contributes to closing the educational digital divide in Colombia.

This study aims to provide solid evidence and practical recommendations. It aspires to significantly improve educational quality in rural settings by empowering teachers with relevant and applicable digital skills in response to the urgency amplified by the COVID-19 pandemic.

METHOD

This research adopts a two-phase methodology focused on data collection and preliminary analysis to investigate the digital empowerment of teachers in rural areas of Colombia. This is in line with Hurtado[10] guidelines on holistic research and its applicability in complex and diverse educational contexts.

Phase 1: Initial Diagnosis and Systematic Review

This phase begins with a comprehensive diagnosis of the current context, assessing the penetration of ICTs in rural areas and teachers' level of digital skills. The systematic review methodology will follow the PRISMA guidelines to ensure a rigorous and relevant selection of previous studies.[11,12,13] The search will be conducted in reputable academic databases, including Scopus and Web of Science, using keywords related to digital skills, teacher training, and rural education. The analysis of these studies will identify gaps, challenges, and opportunities that will inform the development of the teacher training model. The following search string was

implemented to identify relevant literature:

("digital competence" OR "digital literacy" OR "technological skills") AND ("teacher education") AND ("rural") AND ("educational resources" OR "technological challenges").

This search string has been designed to capture a broad spectrum of research on teacher training in digital competencies, specifically in rural contexts. The inclusion of terms such as "digital competence," "digital literacy," and "technological skills," along with "teacher education" and "rural" ensures that the search is aligned with our research objectives.

Database Selection The choice of academic databases such as Scopus and Web of Science is based on their recognized comprehensive and multidisciplinary coverage, essential for accessing cutting-edge literature on digital skills and education. These databases are widely recognized for their quality and breadth of academic coverage, ensuring that the selected studies are highly impactful and relevant.[14,15] Including these databases allows us to capture a broad, high-quality spectrum of current research on teacher training and educational technology in rural contexts.

Data Analysis Strategy The data collected from the selected publications will be analyzed using qualitative and quantitative content analysis techniques. This will include thematic coding to identify and analyze trends and patterns in the literature on digital skills in rural settings. In addition, bibliometric analysis tools will be used to map the density and co-occurrence of key terms, providing a structured view of the areas of focus and gaps in current research.[13,16] These techniques will allow for a more in-depth and systematic interpretation of the data, ensuring that the conclusions and development of the training model are well-founded and aligned with the emerging needs identified in the literature review.

Inclusion Criteria

1. Time frame: studies published between 2018 and 2023 will be included to ensure the timeliness and relevance of the data collected.
2. Language: given that the search chain has been applied in English, studies published in this language will be included.
3. Research Context: studies that examine digital competencies and teacher training in rural contexts will be selected. These studies will identify specific challenges and opportunities for improvement through the use of technological educational resources or by addressing technological challenges.

Exclusion Criteria

1. Publications outside the date range: any study published before 2018 or after 2023 will be excluded.
2. Studies not focused on rural education: research that does not distinguish between urban and rural contexts or focuses exclusively on urban areas will be discarded.
3. Non-academic documents: sources of information not peer-reviewed, including conference reports, opinions, and gray literature, will be excluded to focus on solid and verifiable evidence.

Implementing this search chain and the inclusion and exclusion criteria will ensure accurate and relevant data collection, providing a solid foundation for designing the teacher training model. This methodical approach is essential for developing practical and sustainable solutions that improve the digital skills of teachers in rural areas, responding to the challenges identified and contributing significantly to closing the educational digital divide in Colombia.

Phase 2: Design of the Training Model

Based on the systematic review's diagnosis and findings, a preliminary teacher training model will be designed that integrates the digital skills needed to overcome the identified barriers. This model will be based on the principles of holistic education, seeking not only to improve teachers' technical skills but also to promote an inclusive pedagogical approach that responds to the educational needs of rural areas. The design methodology will be participatory, including input from teachers, ICT experts, and educators to ensure the model is relevant, adaptable, and sustainable.

RESULTS

The systematic review conducted using the specific search chain has yielded significant results, indicating a rich interconnection between digital competencies, teacher training, and educational challenges and resources in rural contexts. Visualization through bibliometric and density maps reveals patterns of thematic connectivity and areas of interest within the academic literature that are fundamental to understanding the current landscape and guiding future research.

Figure 1 illustrates a co-occurrence network analysis of terms, revealing how digital competencies, teacher education, and technological challenges are interconnected in the academic literature on rural education. Nodes represent key terms, while lines indicate the frequency with which they are associated in the research, highlighting the prominence and interrelationship of fundamental concepts.

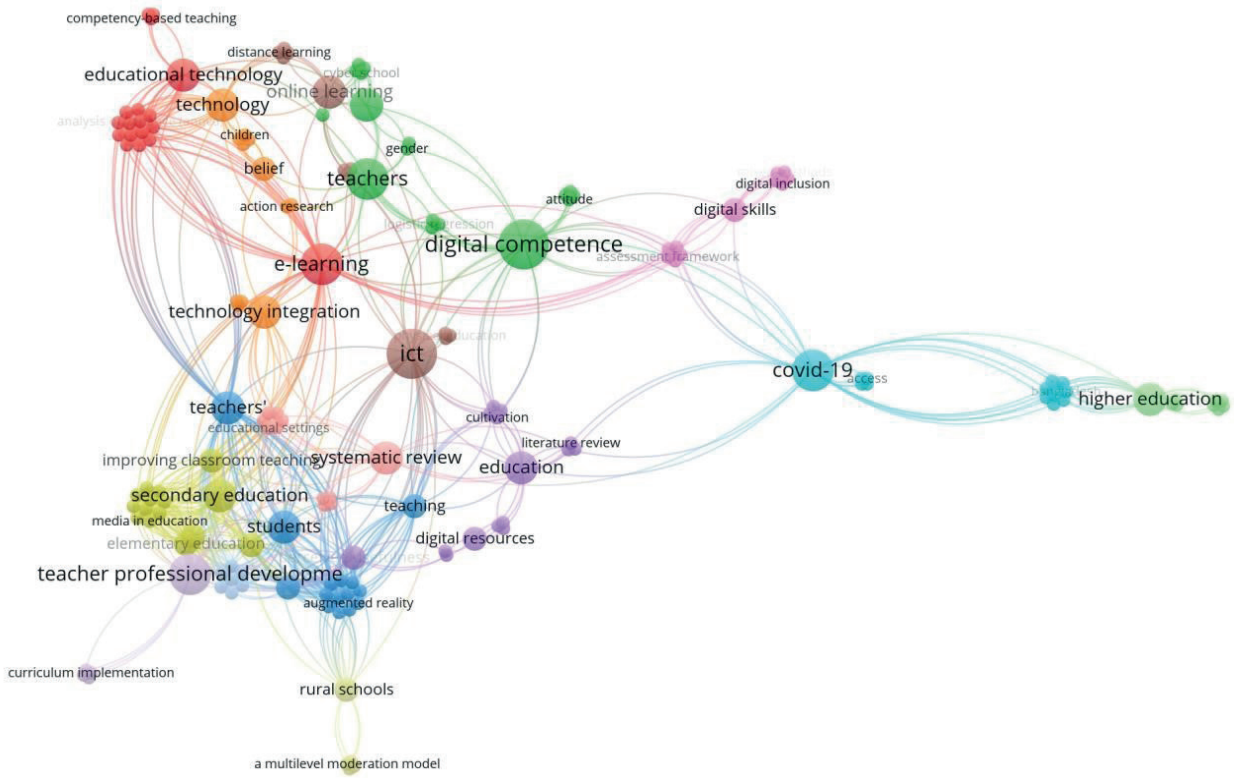

Figure 1. Network of co-occurring terms in digital skills and rural education

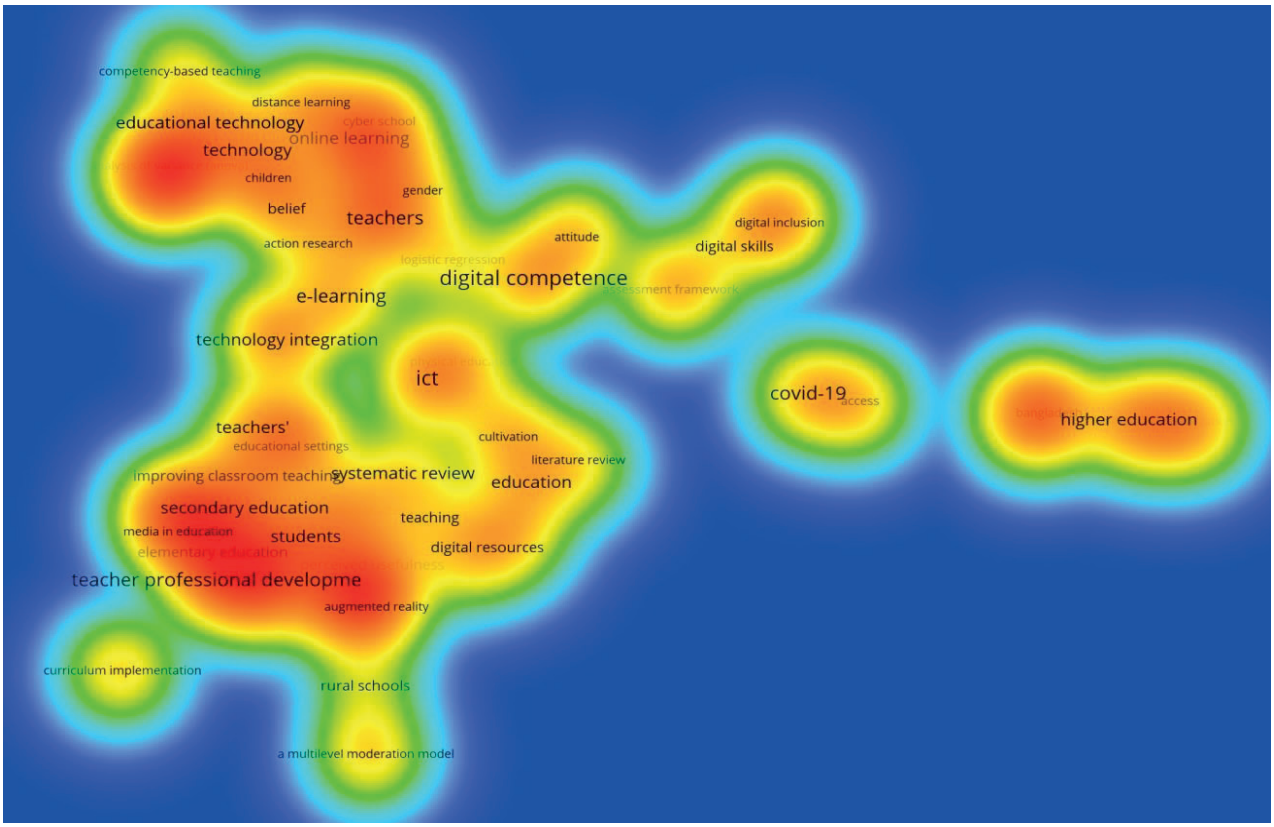

Figure 2. Map of Research Density in Digital Competencies and Teacher Training

Figure 2 presents a density map identifying areas of thematic concentration within the field of digital competencies in rural education. The denser regions indicate a greater clustering of research focused on specific terms, providing an intuitive visualization of the most researched topics and their degree of interrelation.

Figure 3 displays a factor analysis that positions distinctive terms in a multidimensional space, suggesting how certain concepts may represent specialized or emerging niche of study.

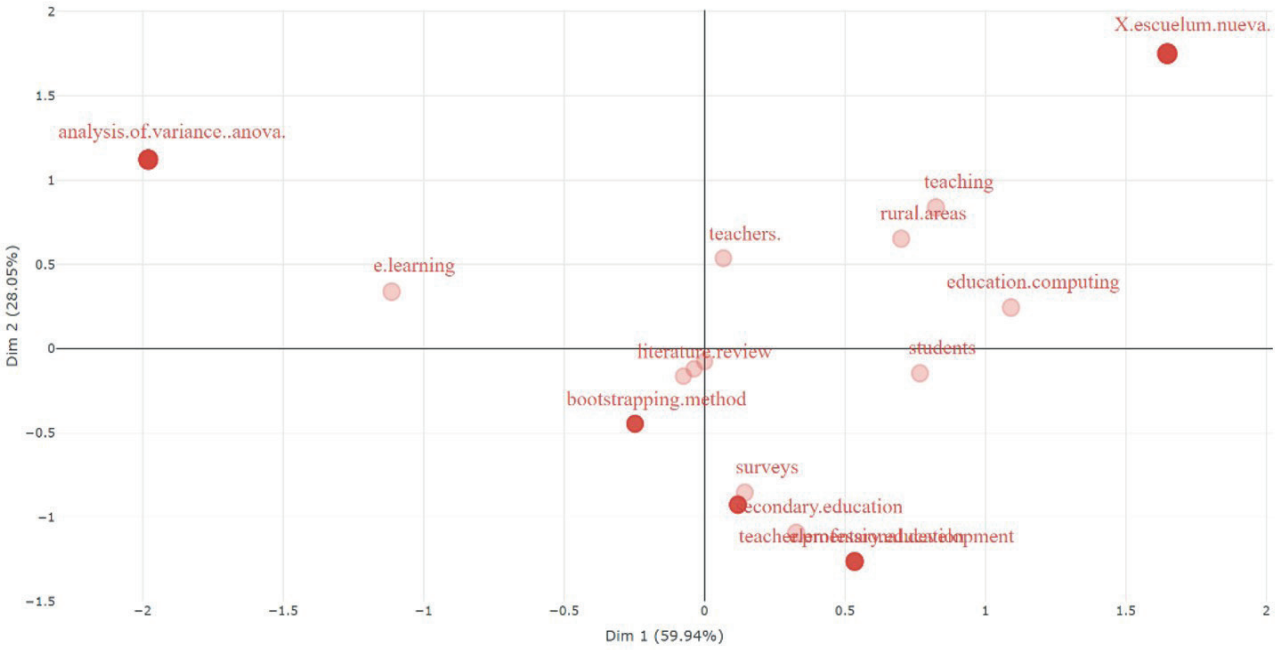

Figure 3. Factor analysis of terms related to ICT in education in rural areas

Table 1 compiles a sample of relevant and noteworthy works in the field, obtained through the systematic literature review conducted in this study. These works, considered fundamental references, can provide a solid foundation for future research in this area.

Table 1. Analysis of the Sharing of Digital Educational Resources by Rural Teachers

Study Analyzed	Purpose	Contributions	Prospects for Continuity
"Differential Analysis of Teachers' Technological Pedagogical Content Knowledge (TPACK) Abilities According to Teaching Stages and Educational Levels"[17]	Examine teachers' TPACK skill levels and whether there are differences according to teaching stages and educational levels.	They found that teachers' TPACK skills are generally high, with significant differences across teaching stages and educational levels.	They suggest further research with a larger and more geographically diverse sample and the use of qualitative methods such as interviews.
"Professional Development on Digital Literacy and Transformative Teaching in a LowIncome Country: A Case Study of Rural Kenya"[18]	Explore culturally sustainable teaching methods aligned with the Kenyan government's initiative for innovative teaching and literacy achievement The Kenyan government has set a goal of achieving universal primary education by 2015 and universal literacy by 2020. To achieve these goals, the government has launched a National Education Plan (NEP) and a National Curriculum (NC) that includes a new curriculum for primary and secondary digital for all students.	They revealed the need for new literacies for students, creativity, collaboration, and creative solutions to overcome technological challenges.	Investigate in greater detail the transferability of findings to other parts of Kenya and rural schools in developing countries more broadly.

"Towards the Revolution and Democratization of Education: A Framework to Overcome Challenges and Explore Opportunities through Industry 4.0"[19]	Propose a framework containing a set of policies and initiatives for society's drivers (industry, government, and academia) to develop Education 4.0.	Creation of a new knowledge block on Education 4.0 that expands and deepens	Further studies with different search criteria are suggested to identify countries with policies and initiatives that could be added to the framework for Triple Helix agents.
"Measuring Rural Teachers' Digital Competence to Communicate with the Educational Community"[20]	Examine the self-assessment of rural teachers' digital competence in Spain for digital communication with the educational community, including students, families, and other teachers.	the existing literature, supporting new research and initiatives on the subject.	Suggest future research with more representative samples and geographical diversity to generalize the results, as well as the use of pre-experimental designs to
"Science teachers' integration of digital resources in education: A survey in rural areas of one Indonesian province"[21]	Develop factors that predict the integration of digital resources by science teachers in rural areas of Indonesia..	It was found that rural teachers have an integrative attitude and medium-high digital competence for communicating with students, families, and colleagues, using digital resources such as blogs, TikTok, Twitter, and Moodle.	measure the effectiveness of MOOC courses in improving teachers' digital competence.
"Effects of teacher- and school-level ICT training on teachers' use of digital educational resources in rural schools in China: A multilevel moderation model"[22]	Explore the relationship between ICT training at teacher and school level and the use of digital educational resources (DER) by teachers in rural schools.	They found that attitude is the most influential factor in the intention to use digital resources, while self-efficacy was not significant. The intention to use was the only significant predictor of actual behavior.	Suggest future research with more representative samples and geographical diversity, as well as observation and teachers in ICT training.
"Rural teachers' sharing of digital educational resources: From motivation to behavior"[23]	Examine the factors that influence the behavior of sharing digital educational resources among rural teachers.	They found that internal motivation and external motivation significantly influence attitudes and sharing behavior, but in different ways. Furthermore, the intention to share and the climate of sharing only had a positive relationship with sharing behavior outside school.	They suggest further research into the quality of sharing behavior, not just frequency, and extending research to other countries or knowledge-sharing contexts.

A comparison of studies focusing on integrating digital educational resources by teachers in rural contexts (table 1) offers a valuable and multifaceted perspective on the progress and challenges inherent in this area of research. A detailed analysis of these comparisons reveals several universal trends, including the decisive influence of motivational factors, both intrinsic and extrinsic, on teachers' technology adoption behavior.[24] Although motivation is presented as a catalyst for the use of educational technologies, it is clear that its effectiveness is modulated by the presence of adequate and accessible infrastructure, as well as institutional and training support.[25,26]

This synthesis also highlights how the geographical and socioeconomic context shapes the educational experience, emphasizing the importance of adapting technological interventions to specific local realities to ensure their relevance and effectiveness.[26] The diversity of contexts examined in the comparative studies highlights the need for a pedagogical approach that is sensitive to regional differences and designed to overcome the technological and structural barriers prevalent in rural areas.[27]

Furthermore, the comparative review indicates that, although common challenges exist, such as limited technological infrastructure and unequal access to digital resources, there is considerable scope for pedagogical innovation and continuous professional development focused on digital competence.[28] This landscape suggests vast ground for future research, particularly about qualitative methods that can provide a deeper understanding of the dynamics of technology integration in teaching.

DISCUSSION

Discussion and comparison with previous studies reveal a gradual but significant shift toward digital inclusion in rural education. However, it also highlights persistent barriers that require specific and sustained attention. The ramifications of our findings suggest that future interventions must be multidimensional, addressing

technological, pedagogical, and socioeconomic aspects to be genuinely effective.

The present research contributes significantly to the field of technology education in rural areas from practical, theoretical, and methodological perspectives. At the pragmatic and empirical level, this study illuminates how targeted and contextually adapted interventions can significantly improve teachers' digital competencies in rural settings, facilitating students' access to a more prosperous and diversified education. From a theoretical perspective, the analysis broadens the understanding of the dynamics between teacher training, the use of technology in teaching and learning, and the specific challenges faced by rural areas, contributing to the existing literature on the digital divide and equity in education.[29,30,31]

This research proposes a comprehensive and original model for teacher training in digital skills and pedagogical support in rural areas. This model called the "Digital Training Model for Rural Teachers (MCDDR)," is structured in four key phases designed to address both the pedagogical and technological needs of teachers in rural settings, thus maximizing the educational possibilities of ICT.[32,33]

Phase 1: Diagnosis and Needs Assessment

This initial phase focuses on identifying teachers' specific needs in terms of digital skills and pedagogical support. It includes using surveys, interviews, and focus groups to gather information on teachers' current level of digital skills and their expectations and challenges. This diagnosis will allow for the customization of the training program.

Phase 2: Training Program Design

Based on the diagnosis results, this phase involves designing a specific training program that addresses the identified gaps. This program will combine theoretical modules on basic and advanced digital skills with practical applications focused on using ICT to enrich pedagogy. Emphasis will be placed on innovative teaching strategies that effectively integrate digital resources into the curriculum.

Phase 3: Implementation and Support

The training program will be implemented through face-to-face and online workshops, ensuring accessibility for all teachers regardless of location. Continuous support is important in this phase, offering teachers personalized advice and technical support to resolve doubts and encourage them to apply what they have learned in their educational contexts.

Phase 4: Evaluation and Feedback

Finally, a comprehensive evaluation of the program will measure its impact on teachers' digital skills development and teaching practice. In addition, participant feedback will be crucial for making adjustments and improving the program. This phase seeks to ensure the long-term sustainability and relevance of the model.

Figure 4 incorporates a pragmatic perspective into the Digital Training Model for Rural Teachers (MCDDR) and illustrates how the model is implemented in environments with varying technological resources. This visualization facilitates understanding of how the MCDDR is adapted and implemented according to the specific conditions of each rural educational context.

Figure 4 highlights two distinct trajectories within the MCDDR model: 'Optimized Training' for contexts with adequate technological infrastructure and 'Minimum Viable Training' for limited technology conditions. These paths illustrate the MCDDR's flexibility and adaptability and underscore its holistic approach, ensuring that all interventions are relevant and practical. This visual outline confirms the model's applicability in various situations, contributing to scientific advancement in teacher training and digital inclusion.

The MCDDR provides a systematic and contextualized approach to digital skills training in rural areas, highlighting the importance of ongoing pedagogical support. Unlike other models, the MCDDR integrates diagnostic and impact assessments as fundamental components, ensuring that training is relevant and practical. This model advocates for improving technical skills and a pedagogical transformation that enables teachers to incorporate ICT in innovative and effective ways in the classroom.

Implementing the Digital Training Model for Rural Teachers (MCDDR) stands out as a promising strategy for addressing the challenges identified in the results of our research. The significant interconnection between digital skills and educational challenges in rural contexts underscores the need for a holistic approach such as that proposed by the MCDDR. This model responds to technical needs and focuses on pedagogical and socioeconomic training, ensuring that interventions are culturally relevant and sustainable over time. The discussion and analysis of these aspects provide a deeper understanding of how digital empowerment can drive significant change in rural education, leading to tangible improvements in teaching quality and student learning outcomes. This detailed assessment supports the practical application of the study's findings and reinforces the importance of further research and adaptation of this model to maximize its impact.

Figure 4. Visualization of Technological Resources for Rural Teacher Training

Methodologically, the holistic approach adopted to examine technology integration in rural education proposes a replicable and adaptable model that could be applied to different educational contexts and learning needs. This model prioritizes technological infrastructure and teachers' professional and pedagogical development, an essential consideration for the long-term effectiveness of any technological intervention in education.

This study suggests a promising path toward the democratization of technology education. By providing a detailed understanding of how to overcome barriers to technology integration in rural settings, this research lays a solid foundation for future initiatives designed to close the educational digital divide. This research highlights the urgent need to address equity in access to technology education, ensuring that all students, regardless of their geographic location or socioeconomic status, can participate fully in 21st-century society.

CONCLUSIONS

This research has highlighted the fundamental importance of strengthening digital skills among teachers in rural areas, proposing an innovative model called the Digital Training Model for Rural Teachers (MCDDR). Through this study, we have identified persistent barriers that hinder digital inclusion in rural education, including challenges related to technological infrastructure, access to quality educational resources, and the need for adequate teacher training in digital skills. However, it has been demonstrated that carefully designed and contextualized interventions can make a significant difference, significantly improving teachers' digital skills and, therefore, enriching students' access to a diversified education.

The MCDDR stands out for offering a systematic and well-structured approach that ranges from initial needs assessment to final evaluation and feedback, emphasizing the importance of adapting training to the specific and changing conditions of rural environments. This model focuses on improving technical skills and promotes pedagogical transformation, enabling teachers to integrate information and communication technologies (ICT) in innovative ways into their educational practices.

In addition, this research's findings provide a valuable starting point for future studies, offering a methodological framework that can be applied and evaluated in different educational contexts. This opens the door to a more in-depth exploration of the long-term impact of such training programs on teachers' pedagogical practices and student learning outcomes.

This study underscores the urgency and feasibility of closing the educational digital divide in rural areas through a comprehensive, evidence-based teacher training strategy. By implementing the MCDDR, a promising path toward improving digital inclusion and academic quality in rural settings is proposed, ensuring that all students, regardless of location, have access to equitable and enriching educational opportunities in the contemporary digital society.

Implementing the Digital Training Model for Rural Teachers (MCDDR) has proven to be an effective strategy for addressing the digital divide in rural areas of Colombia. Through this study, it has been shown that a well-structured and contextually adapted approach can significantly improve teachers' digital skills, thus contributing to a more inclusive and equitable education. Future research must continue to explore and expand this model, considering variables such as the long-term impact of training on teaching practices and student learning outcomes. In addition, it is recommended that the replicability of the MCDDR in other rural contexts, both nationally and internationally, be examined to validate its effectiveness and adjust its components according to specific local needs.

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