Future-Proofing Small Schools: Rethinking Education with AI

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Abstract: This study investigates the transformative role of Artificial Intelligence (AI) in revitalising teaching practices in small and rural schools, addressing their unique challenges. Combining a systematic literature review and a participatory imagination lab (workshop) with Italian teachers, the research adopts a dual methodological approach. The review identifies key focus areas for action, emphasising how AI can address critical issues in "non-standard" educational contexts such as multigrade classrooms, teacher turnover, and geographical isolation. The imagination lab complements this by exploring how these challenges are recognised in the Italian context and what solutions are envisioned using technology cards. This participatory methodology enables the co-design of potential AI-driven strategies tailored to real-world scenarios. The study underscores the significance of small schools as unique laboratories for educational innovation, highlighting the replicability and scalability of this approach. Extending such methods to a broader network of small schools offers the potential to refine technological solutions, develop tailored intervention clusters, and foster evidence-based, scalable policies for equitable and resilient education in similar contexts worldwide.

1 INTRODUCTION

Small and rural schools represent a worldwide educational reality, with unique characteristics and shared challenges that define their role within national education systems. These institutions, operating in a "non-standard" context, challenge traditional school organisational models as they serve communities in remote, mountainous, insular, or economically disadvantaged areas, often constituting the only educational provision available. According to the OECD (2021), in member countries, these schools account for approximately 20% of total institutions, providing essential education in contexts characterised by low population density and limited access to services.

The management of multigrade classes, high teacher turnover, limited access to resources, and the digital divide are just some of the challenges these educational contexts face (Echazarra and Radinger, 2019).

Rural schools, as highlighted in the OECD *Learning in Rural Schools report,* face significant challenges across OECD countries. One critical issue is resource availability: rural schools often have fewer students, which increases per-student costs and limits economies of scale. On average, secondary rural schools in OECD countries have 369 students compared to 890 in urban schools, which is

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particularly evident in countries like Mexico, Portugal, and the United States, where the rural-urban difference exceeds 1,000 students. In countries like Australia and New Zealand, up to half of primary students in rural schools are taught in multigrade classrooms, a necessity due to small student populations, while in remote areas this figure rises to 90%. Similarly, in Europe, rural families often have limited school choice; for example, in Spain, only 4% of rural students attend private schools compared to 53% in urban areas, highlighting structural inequities. Access to digital tools and the internet varies significantly: in Mexico, only 42% of rural school computers are connected to the internet, compared to 90% in urban schools. This disparity highlights the digital divide, which exacerbates educational inequality. Furthermore, transportation costs for rural schools are higher, affecting access to after-school programs and professional development opportunities. In Italy, small and rural schools constitute a significant part of the education system, with over 11,600 institutions serving 48% of students in the country's inner areas (Bartolini et al., 2021; 2023). These schools face difficulties in ensuring continuity of education due to teacher turnover and the management of multigrade classes in contexts often characterised by geographical and cultural isolation (Mangione and Cannella, 2020), where the risk of educational disconnection exacerbates existing territorial disparities (Pedro et al., 2019; UNICEF, 2020).

The COVID-19 pandemic, which highlighted the disparity between rural and urban schools, heightened their vulnerability. According to UNESCO (2021), over 40% of students in global rural areas lacked adequate resources for distance learning, leading to a significant increase in dropout risk. In sub-Saharan Africa, the dropout rate in rural schools rose by 15% during the pandemic, with similar trends observed in many parts of South Asia and Latin America (Dang et al., 2021). Even in developed countries such as Canada and Australia, the pandemic underlined the urgent need for innovative strategies to ensure educational continuity and reduce the urban-rural divide (OECD, 2022). These numbers show how important the issue is on a global scale and how quickly we need to find specific ways to help small and rural schools deal with their problems to enable them to reach their full potential as sources of innovation and educational resilience.

These disparities underscore the global urgency of developing targeted interventions for rural schools, enabling them to serve as hubs of resilience and innovation rather than as symbols of educational inequity. To tackle these challenges, rural education systems must adopt innovative practices that leverage digital tools, promote teacher training tailored to rural needs, and strengthen local capacity. By doing so, rural schools can transform into models of educational equity and resilience, contributing to broader societal progress.

Digital technologies, especially Artificial Intelligence (AI), could represent a promising response to these challenges. For example, could allow small schools to overcome contextual limitations and ensure equitable access to quality education (Panciroli and Rivoltella, 2023). Or yet, AI could offer significant opportunities to enhance education by facilitating personalised learning and inclusion. Virtual tutors and adaptive platforms could support students in customising their learning experience, monitoring progress in real time, and adapting teaching strategies to specific needs (Mangione, 2024).Thinking about the importance of networking to overcome isolation AI could also enable the creation of collaborative school networks, expanding the reach of small schools through joint projects and the exchange of educational resources or making small schools more attractive to qualified teachers, mitigating the problem of turnover and ensuring greater educational continuity.

Combining cutting-edge AI technologies with new ways of doing things could make these small schools more competitive in the education field, closing the gap with schools in cities and promoting educational equality (Mangione and De Santis, 2024). The adoption of AI would not only address contingent challenges but could also offer an opportunity to rethink the mission of small schools. Through the implementation of innovative solutions, these schools could become laboratories for educational experimentation, promoting more equitable, inclusive, and sustainable education (Mangione et al. 2023). In this way, AI could contribute not only to improving teaching practices but also to strengthening the role of small schools as drivers of cultural and social development in their communities (White and Corbett 2014).

2 RESEARCH QUESTIONS AND METHODOLOGIES: BUILDING FUTURE SCENARIOS FOR AI IN SMALL SCHOOLS

Italian small schools, primarily located in inland, mountainous, and insular areas, represent a "non-

standard" educational model that addresses unique challenges. These institutions often serve as the only educational hubs within local communities, playing a crucial role in maintaining social and cultural cohesion in these territories. According to Bartolini et al, 2023, *Atlas of Small Schools*, Italy has over 11,600 small schools, catering to approximately 48% of all students in the national educational system, demonstrating the pervasive and persistent relevance of this phenomenon (Bartolini et al., 2021).

For years, INDIRE has been contributing to the improvement of educational offerings and teaching-learning experiences in non-standard educational situations through continuous *service research* (Cannella, Mangione and Rivoltella, 2021; Mangione, 2024a). This approach views research as a service to educational processes, addressing criticisms of educational research institutions for their alleged "failure to respond to the demands of schools" or "institutional disengagement."

By doing research in these contexts, Italian small schools become an epistemic context—a privileged space to identify research questions and test the outcomes of investigations, contributing to the advancement of pedagogical science and enhancing the most fragile educational realities (Mangione, 2024b).

2.1 The Research Questions

We identified two complementary research questions within this framework.

The first focuses on the analysis of the existing "scientific discourse" concerning AI in rural educational contexts: ***RQ1. What are the primary application domains of AI in rural educational contexts?***

This question seeks to explore the dimensions identified in the literature as fundamental for applying AI in remote, non-standard contexts characterised by limited access to resources. The necessity of revitalising educational practices in these contexts is a globally recognised issue, as highlighted in international reports (UNESCO, 2021; Trendov, Varas and Zeng, 2019), which emphasise the role of AI in overcoming territorial disparities and introducing innovative teaching practices in geographically and culturally isolated schools.

The second question shifts from the theoretical dimension to the local one, contextualising the global reflections into the specific context of Italian small schools: ***RQ2. What are the problem scenarios specific to Italian small schools, and what AI-driven solutions can be proposed to address them?***

This question aims to relate global evidence to situated problems. The goal is to understand how AI technologies can be designed or adapted to address concrete challenges, such as managing multigrade classes, ensuring educational continuity amid teacher turnover, and mitigating the risk of social exclusion for students in marginal areas (Mangione and Cannella, 2020; Mangione, 2023). This step is crucial to orient research towards identifying technologies that address existing problems and radically rethink educational experiences, imagining future scenarios and innovative solutions.

The duality of these questions is not only methodological but also epistemological: on one hand, the aim is to understand whether and how AI can already be considered a strategic opportunity for rural and marginal educational contexts; on the other hand, the goal is to ground this reflection in a participatory process involving teachers and local stakeholders to define realistic and sustainable use cases.

2.2 Research Methodology

The research questions require a methodology that alternates theoretical analysis with practical experimentation to root technological innovation in concrete contexts, avoid standardised approaches, and promote solutions that respect the peculiarities of small schools.

In the first phase - to address the first research question (RQ1) *What are the primary application domains of AI in rural educational contexts?* - a scoping review was conducted. This methodology is particularly suited to providing a comprehensive overview of a broad topic such as AI in rural education (Peterson et al., 2017). Following the model proposed by Arksey and O'Malley (2005) and previously applied by Mangione and De Santis (2024), the scoping review was developed through five phases. After identifying the research question, "What does the literature say about AI and rural education?", a secondary question was defined to identify the main application domains of AI in rural education contexts. We identified studies using databases such as Web of Science, Scopus, and Google Scholar. Initial keywords included "artificial intelligence" and "rural education". Subsequently, we expanded the query to include terms such as "machine learning", "deep learning", "artificial education", "rural school", and "small school". Inclusion criteria required that studies be published in English, be open-access, and be dated from 2010 onward. The scoping review, which included a quantitative analysis and a thematic summary of AI's main uses, led to the focus being put

on how AI can be used to improve teaching in rural schools (Mangione and De Santis, 2024). After that, the investigation proceeded with what Arksey and O'Malley (2005) identify as the sixth and optional final phase of a scoping review: consulting stakeholders to offer additional sources of information, perspectives, meanings, and applicability. Through a "spoken reflection" process involving national and international experts selected for their knowledge of small school contexts, opportunities for small schools were identified by connecting the stimulus questions to the dimensions emerging from the scoping review, converging on specific challenges for revitalising teaching in small schools.

In the second phase - to address the second research question (RQ2) *What are the problem scenarios specific to Italian small schools, and what AI-driven solutions can be proposed to address them?* - a participatory workshop was conducted based on the Design Thinking (DT) methodology (Brown, 2009). This approach, increasingly used in educational research, is particularly effective for addressing complex problems and developing innovative solutions in contexts characterised by structural constraints, such as small schools (Razzouk and Shute, 2012). A key aspect of the workshop was the use of technology cards to foster imaginative, project-based thinking and define future scenarios (Sanders and Stappers, 2014). Engaging 46 teachers from primary and lower secondary schools, the activities followed the DT stages. The participants began by sharing their experiences and challenges through a story-share and capture tool, fostering empathy and highlighting issues like multigrade class management, geographic isolation, and teacher turnover. Building on this, they collaboratively defined problems using "How Might We…?" (HMW) questions to frame challenges constructively, setting the stage for the ideation phase. The introduction of technology cards, describing current or potential AI technologies and their educational applications, encouraged innovative thinking. They have been defined in the context of the AI-wareness board game to engage teachers in initial thinking about the use of AI in school settings (Re et al., 2024). This approach, recognised in participatory design literature (van Amstel et al., 2012), enabled the exploration of creative solutions tailored to the challenges identified, proving particularly useful in educational research (Wölfel & Merritt, 2013).Through this process, the workshop not only identified potential applications of AI but also laid the groundwork for a transformative vision that reimagines the role of emerging technologies in addressing the unique challenges of small schools. The results of these methodologies go beyond identifying AI applications. They propose a transformative vision capable of fundamentally rethinking the role of emerging technologies in the context of small schools. The results will be presented in the subsequent sections.

3 AI IN RURAL SCHOOLS: INSIGHT FROM THE SCOPING REVIEW

The scoping review led to the realisation of an exploratory study, which focused on the 19 studies that met the inclusion criteria. After analysing the studies, we were able to map them by examining recurring themes and subthemes.

3.1 Key Themes and Areas of Focus

The review identified four main thematic clusters (Table 1).

Most of the papers (12) fall into cluster 1, "AI for revitalising teaching and learning processes". These studies focus on exploring the applications of AI in the field of education, with the main objective of reducing the existing disparities in the quality of education between urban and rural contexts. In particular, the areas of application include the use of AI to personalise learning, improve disciplinary teaching and distance learning processes, and to integrate learning AI in K-9 and K-12 syllabi to create engaging learning experiences.

Other studies (3) can be attributed to cluster 2, "AI for teacher professional development". This research is based on the premise that it is necessary to overcome the professional isolation of teachers, which often characterises rural contexts, focusing on teacher training as a lever to improve access to educational resources and to promote equity (Mangione, Pieri and De Santis, 2023). Some studies explore AI's potential to enhance resource sharing and peer collaboration (Wang, 2020), while others focus on teachers' perceptions and ethical challenges (Chounta et al., 2022). Edwards and Cheok (2018), propose AI and robotics as tools to address teacher shortages, ensuring teachers are prepared to integrate these technologies while maintaining their role in social interaction and emotional support (Gentile et al., 2023).

The contributions (2) attributable to cluster 3, "AI for developing predictive models of student interest

and success", highlight the potential of AI to construct predictive models that enhance educational outcomes by personalising learning and providing targeted student support.

The studies (2) categorised under cluster 4, "AI for school service management and risk prediction", focus on the application of AI to enhance administration, optimise transportation, and improve safety and accessibility in disadvantaged or isolated schools.

It is important to highlight that the identified themes and sub-themes are interconnected, forming a complex yet integrated ecosystem for potential applications of AI in education. For instance, the implementation of AI-based personalised learning tools (a sub-theme of the first cluster) requires adequate training for teachers (the second cluster). Teachers must acquire specific skills to utilise these technologies and adapt them to their educational contexts. Moreover, these tools generate a significant volume of student data, enabling the creation of sophisticated predictive models (the third cluster). A fragmented approach would risk reducing the positive impact of technology and widening existing inequalities, especially in rural or resource-limited contexts. Therefore, an integrated strategy that fosters collaboration between researchers and teachers is essential to ensure that solutions are pedagogically relevant and socially inclusive.

3.2 The Studies Guiding the Design of the Participatory Workshop

The studies most closely related to the teaching context, especially those from cluster 1 and some from cluster 2, guided the research group in the next phases and the design of the participatory workshop for small-school teachers. This analysis provided insight on how to effectively use AI to address the unique needs of this educational setting. Many sources highlight the AI's potential to personalise learning experiences. For example, Yang and Zheng (2021) argue that, despite existing economic challenges, AI presents a concrete solution to reduce inequalities in the distribution of educational resources. This technology can offer students in remote areas of China the chance to expand their knowledge and horizons. One advantage of AI, as highlighted by the authors, is the possibility of providing personalised instruction by analysing students' progress data. This analysis helps identify the so-called "dead zones" in their learning and allows educators to respond in a targeted way to individual needs. Wang and Lin (2019) also underline how AI and big data are transforming education by fostering personalised, ubiquitous, and lifelong learning.

Table 1: Reference distribution: themes and sub-themes

Themes	Sub-themes	References
AI for revitalising teaching and learning processes	- AI for the personalisation of learning - Intelligent Tutoring Systems - Automated assessment tools - Integrating AI into K-9 and K-12 education - AI to improve distance and disciplinary teaching	Gong et al. (2023) Gong et al. (2020) Iyer (2022) Iyer (2019) Jiang (2021) Jiang et Cheong (2023) Rasheed et al. (2021) Vanderberg et al. (2022) Wang and Lin (2019) Xiao et al. (2022) Yang and Zheng (2021)
AI for teacher professional development	- Teachers' knowledge, perceptions and attitudes towards AI and ethical challenges - AI for the continuous professional development of teachers - Teacher training on the use of AI	Chounta et al. (2022) Edwards and Cheok (2018) Wang (2020)
AI for developing predictive models of student interest and success	- Predicting student interest in higher education (orientation) - Early identification of learning difficulties and personalised support	Nuankaew and Nuankaew (2022) Saravanan et al. (2021)
AI for school service management and risk prediction	- Transport optimisation - Assessment of the vulnerability of schools to natural events - Optimisation of resource allocation	De Souza Lima et al. (2023) Yousefi et al. (2020) Zhou (2022)

The implementation of personalised education, which is not possible in traditional education due to limitations like teacher shortages, can help address the imbalance in educational resources and help address social problems by creating a new ecology of educational technology. Chounta et al. (2022) present a study on Estonian teachers regarding the use of AI as a tool to support teaching in K-12 schools. The research is interesting because it reveals that teachers have a positive view of AI's educational potential, particularly its ability to personalise learning. In their paper, the authors cite Intelligent Tutoring Systems (ITS) as a relevant example of how AI can improve access to quality education, especially in rural areas. ITS are characterised by their capacity to create personalised learning paths that adapt to each student's pace and learning style. In addition, ITS are valuable tools for accessing, adapting and using multilingual content. Their advanced natural language processing capabilities can enhance learning in multilingual environments, enabling students to interact with the system in their native languages. This approach makes the educational experience more inclusive and accessible. For example, AI could be integrated into a Learning Management System (LMS) to automatically translate content, allowing students from diverse language backgrounds to easily access information. Iyer (2019) also analyses the Indian context to highlight the complex challenge represented by linguistic diversity in education. With many regional languages, India faces significant challenges in creating and distributing educational content that is accessible to all students. In response to this issue, the research suggests leveraging AI as an innovative solution by integrating automatic translation systems into mobile devices for learning. These systems would allow students to access translations of words or sentences anytime, making it easier to understand teaching materials and promoting inclusion. Other researchers (Edwards and Cheok, 2018) propose the use of robots as teachers, especially in situations where there is a shortage of teaching staff. In their paper, the authors present a project aimed at developing a prototype teacher robot and outline its potential capabilities for delivering educational content and facilitating social interactions. The article also discusses the ethical and technological challenges associated with this concept, considering the conflicting opinions on whether robots can fully replace human teachers; the authors suggest future research directions to address AI's current limitations in the educational field. Another theme emerging from the studies is the use of AI to develop more efficient assessment systems that address students' different backgrounds and learning styles. AI can automate repetitive assessment tasks, such as marking multiple-choice quizzes or analysing short answers, which saves teachers valuable time for more complex responsibilities, such as providing individual support to students (Yang and Zheng, 2021). Furthermore, AI can offer students immediate feedback during exercises or activities, helping them to identify and correct errors in real-time (Chounta et al., 2022). This timely feedback fosters a deeper understanding of concepts and more active learning. The analysed contributions propose a critical reflection regarding the integration of AI in evaluations, which should be accompanied by strategies aimed at preventing systemic biases and promoting a collaborative approach in which AI supports, but does not replace, human experience. In other studies (Gong et al., 2020; Vandenberg et al., 2022), research on AI-based education focuses on its integration into national curricula. For example, Gong et al. (2020) conducted an in-depth study on the current state of AI education in Qingdao, China. One of the main goals is to develop a curriculum that integrates the concepts and applications of AI across disciplines, providing students with a comprehensive understanding of AI and its impact on society. This need is particularly relevant in rural areas, where educational resources are often limited, and opportunities for AI learning are fewer compared to urban settings. Vandenberg's (2022) presents research that investigates the potential of video games to enhance interest and promote understanding of AI and computing concepts. Through game design activities, students can learn the basic principles of AI in a practical and creative way, promoting active engagement and meaningful learning. The analysis of the contributions that emerged from the scoping review highlighted how the solutions and these technological tools appear to be promising resources for addressing the specific and complex challenges that characterise these environments and offer innovative opportunities for improving the effectiveness and equity of education in these contexts.

4 THE EXPERTS' PERSPECTIVE: CHALLENGES AND OPPORTUNITIES FOR SMALL SCHOOLS

The themes from the scoping review guided the development of questions for participatory interviews with Italian and international experts about small

schools. The interviews revealed a consensus on the importance of AI as a tool to reduce the educational gap between urban and rural schools (Mangione and De Santis, 2024). Experts identify that AI provides real-time feedback to teachers, allowing immediate changes in their teaching methods. AI can also be combined with gamification, which makes learning more engaging and tailored for students, helping them stay motivated and included. Another key point was AI's role in breaking down language barriers by using translation technology. This makes educational materials accessible to students who speak different languages and encourages schools in different countries to work together. AI also supports teachers in managing classrooms with students of different ages and levels (Perna, et al. 2024). If a teacher is absent, AI can provide online resources, so education continues. Additionally, AI can strengthen connections in isolated school communities by creating networks that involve everyone. Overall, experts agreed that AI should be a helpful tool in education, not a replacement for teachers (Gentile et al., 2023). Its positive impact depends on focusing on students' needs and recognising the important role teachers play in education.

5 IMAGINING FUTURE SCENARIOS: THE WORKSHOP

The workshop "Future Scenarios: AI for Small Schools" engaged 46 teachers to explore how AI can personalise learning and enhance teaching, focusing on bridging urban-rural gaps. The participants were divided into six groups based on school grades, to address common challenges and opportunities. A DT approach was adopted, combining theory and collaboration to co-construct future scenarios addressing AI in "non-standard" education, focusing on the empathy, definition, and ideation phases, thus encouraging critical reflection on AI's benefits and challenges (d.school, 2010; d.school, 2018).

5.1 Phase 1: Empathy

The empathy phase explored challenges in small schools by leveraging teachers' expertise to identify common issues and potential solutions. To facilitate the process, participants were given an adapted version of the story-share and capture tool (d.school. 2010), focusing on context, actors, needs, and problems. This collaborative approach facilitated narration, active listening, note-taking, and the synthesis of shared insights. During this phase, each group member shared their observations, highlighting quotes, surprises, and significant details through post-it notes, which were then grouped to identify common themes and patterns. The ultimate goal of this activity was to fully understand their experiences, find out their needs in relation to the research theme, and thus initiate a collective reflection on possible solutions.

5.2 Phase 2: Definition

Each group of participants analysed and discussed the main challenges that emerged from their shared stories (Table 2). This step favoured a common understanding of the context and priorities, highlighting the similarities between the experiences that arose. Starting from the themes which emerged, common elements were identified between the different schools, leading to the creation of a shared scenario helping to narrow down the problem.

This process enabled the framing of the 'How Might We...?' (HMW) question, a fundamental step that translated the identified challenges into a constructive and creative question. The HMW question is a short question that launches the ideation phase and is formulated in such a way that it is broad enough to include a wide range of solutions, but at the same time focused enough to provide useful boundaries (d.school, 2018). The question, aimed at circumscribing the problem in a constructive and creative way, helps participants in the process of translating challenges into questions that open up problem-solving, leading to the next stage of the workshop. Group 1 worked on schools located in areas with poor connections, characterised by multi-grade or overcrowded classes. In this context, low motivation was identified as the main problem. This phenomenon is associated with geographical isolation, which limits access to diversified educational experiences, and the complexity of managing heterogeneous classes. Emerging needs include training teachers and offering students customised orientation paths to stimulate their interest and active participation. The HMW question formulated by the group is: "HMW increase motivation?". This question highlights the importance of simultaneously addressing motivational, pedagogical, and organisational aspects.

Group 2 focused on secondary school and the need for interventions in students and teachers' conscious and correct use of AI. The problem limits the educational potential of AI and creates inequalities in access to educational opportunities. The group highlighted the need to develop training paths for all

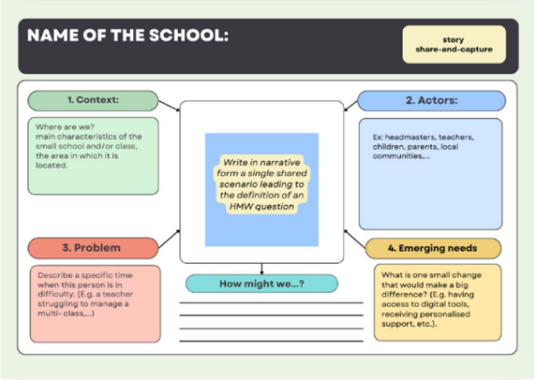

Figure 1: Poster layout for the empathy and definition phase.

school stakeholders (students, teachers, and families) and to improve school infrastructure to support a more effective and inclusive use of technology. The HMW question summarising these needs is: 'HMW develop an informed use of AI to support learning?'. This perspective emphasises the need to combine technological innovation with cultural education.

Group 3 analysed the context of an omnicomprehensive institute with a multi-grade class from first to fifth primary, in which more than 30% of the students are of foreign origin. The main problem concerns learning Italian as a second language (L2), a barrier that hinders both school success and social inclusion among foreign students. The group identified the need to increase the number of teachers supporting the classes and to introduce technological tools to facilitate language learning. The HMW question is: 'HMW use language mediators supported by AI?'. The answer to this question requires an integrated approach that combines technological and pedagogical solutions to foster language inclusion.

Group 4 focused its reflection on challenges related to educational poverty, analysing a school context characterised by frequent teacher turnover, educational discontinuity and a strong need for affective and social inclusion. It emerged that meeting these needs, requires stable and inclusive educational pathways supported by technological tools. The HMW question posed by the group is: 'HMW ensure continuity?'. This question invites reflection on the need for a structural intervention to promote stability and inclusion.

5.3 Phase 3: Ideation

Following the HMW question, the ideation phase encouraged broad exploration of solutions through brainstorming, emphasising creativity and collaboration (d.school, 2010; d.school, 2018). Using the 'Yes, And!' method, participants built on each other's ideas to foster innovation. Technology cards from the AI-wareness board game (Re et al., 2024) served as creative constraints, inspiring AI-driven solutions tailored to educational challenges. With this approach, the groups began to develop 'game-changing' ideas that could lead to transformations by introducing AI. The solutions that emerged from this co-creation process were not limited to individual proposals; in fact, each group could select 3 technology cards that would lead to the construction of a future scenario (Table 3). This scenario provided a clear and inspiring vision, outlining how the school environment could evolve through the strategic use of AI.

Table 2: Group results.

Group	Context	Problems	Needs	HMW
1	Isolation Multi-grade classes	Low student motivation	Teacher training Personalised guidance	*HMW increase motivation?*
2	Secondary school Conscious use of technology	Unconscious and incorrect use of AI	Training for an informed use of AI	*HMW develop a conscious use of AI to support learning?*
3	Multi-grade class Foreign students	Italian L2	Increased number of teachers	*HMW use linguistic mediators supported by AI?*
4	Area with educational poverty	Lack of educational continuity Frequent teacher turnover Prejudices	Social and cultural inclusion	*HMW ensure continuity?*

Figure 2: Poster layout for the ideation phase.

Table 3: Technology cards chosen by each group.

Group	Card 1	Card 2	Card 3
1	Intelligent LMSs	Multimodal Intelligent Assistants	Intelligent Tutoring Systems
2	Intelligent Tutoring Systems; LLM-based chatbots	Intelligent classrooms; other technology	Expert Systems
3	Multimodal Intelligent Assistants	Intelligent Tutoring Systems	/
4	Intelligent Tutoring Systems	Writing assistants	AI-based maths solvers

Group 1 focused on increasing motivation in isolated school contexts with heterogeneous classes, linking motivation problems with the potential offered by the chosen technologies. Starting with intelligent LSMs, intelligent multimodal assistants, and intelligent tutoring systems, the imagined future scenario proposes an integrated learning support system designed to increase motivation. Classes, although heterogeneous, benefit from intelligent tools that personalise the educational experience and offer innovative solutions to logistical and motivational challenges. Thanks to these technologies, multi-grade schools turn into innovative laboratories for experimenting with new educational methodologies. The school community of motivated students and teachers is an example of how AI can turn educational challenges into opportunities, reducing inequalities caused by geographical isolation. It is an approach that aims to increase student motivation (with more engaging and relevant learning experiences), support teachers in managing heterogeneous classrooms, and foster inclusion by overcoming geographical and logistical barriers through technology.

Group 2 focused on the use of AI to improve administration and promote technology-aware use in schools. The chosen cards included intelligent tutoring systems, LLM-based chatbots, intelligent classrooms, and expert systems. The group imagined a future in which secondary school, starting from a situation of infrastructural and cultural difficulties concerning the use of AI, becomes a role model for digital awareness. By integrating AI to support administrative and teaching activities, a systemic change that involves students, teachers, and families is promoted. The group proposed the use of AI tools to improve the search for funding and calls for tenders, making it easier to find economic resources, often not intended for small schools. The question 'HMW develop an informed use of learning support?' highlights a seeming discrepancy with the proposed future scenario in which AI is used to facilitate the search and finding of tenders and funds in institutional portals to support planning at the administrative level. However, the two plans find a meeting point insofar as finding calls and funding could have an immediate impact by combining two fronts: on the one hand, AI tools to improve administrative management, and on the other, training and workshops to create a digitally aware culture. Therefore, it serves as an illustration of how a systemic and collaborative vision can effectively tackle a complex problem.

Group 3 identified an emerging need for increased support in the classroom, proposing the adoption of language mediators supported by AI as a solution. The future scenario foresees the use of multimodal assistants to create interactive learning experiences, such as simulations and multimedia activities, that help students improve language skills. Intelligent tutoring systems would offer customised paths based on the specific needs of each pupil, promoting not only language learning but also integration into the school environment. This system improves students' language skills and fosters greater social cohesion leading to a more inclusive school environment. The future scenario imagines a school in which AI does not replace the role of teachers but supports them in responding to complex challenges.

Group 4 emphasised the need to ensure educational continuity in a school characterised by educational poverty and a frequent teacher turnover. The selected technologies include intelligent tutoring systems, writing assistants, and AI-based mathematics solvers. The imagined scenario involves an AI-based tutoring system, which by creating an 'educational memory' ensures continuity in learning paths, even when teachers change. Writing assistants

and maths solvers have been proposed as practical tools to improve students' academic skills, with a focus on inclusion, support and educational stability. In the future scenario, with these solutions, the school becomes a model for educational innovation in contexts of social and cultural poverty. The intelligent tutoring system improves educational continuity and creates an inclusive school environment where students and teachers feel supported and motivated. The collaboration between schools, families, and the territory is strengthened, creating a cohesive and resilient educational community.

6 DISCUSSION AND RESEARCH PERSPECTIVES

The research presented represents a pioneering contribution to revitalising teaching in small and rural schools, proposing an approach that combines scientific rigour with active teacher participation. Small schools, as highlighted in the international literature, represent a privileged context for experimenting with educational innovations due to their ability to adapt to territorial specificities and local challenges (Bartolini et al., 2021; Mangione et al., 2023). However, these institutions often face critical challenges, such as managing heterogeneous and multigrade classes, teacher turnover, and geographical isolation (OECD, 2020; Corbett & White, 2014). Within this context, the revitalisation of teaching, understood as the adoption of innovative pedagogical approaches supported by AI, emerges as a crucial strategy.

At the same time, while the introduction of AI in small schools offers promising opportunities, it is essential to acknowledge the challenges related to its implementation. Limited access to digital infrastructure, unstable broadband connectivity, and the need for targeted teacher training represent significant barriers. AI should not be viewed as a universal solution to educational challenges but rather as a tool that, when properly contextualized, can complement and support existing pedagogical practices.

The systematic review of the literature conducted in this research identified four main clusters of AI applications in educational contexts, with the cluster dedicated to the revitalisation of teaching offering the most relevant evidence for the Italian pilot case. Recent studies demonstrate how AI-based tools, such as ITS and adaptive platforms, can improve access to educational resources and effectively personalise learning, particularly in resource-constrained contexts (Yang and Zheng, 2021; Xiao et al., 2022).

The DT methodology used in the workshops effectively addressed the complexity of small schools' educational challenges. Structured into empathy, definition, and ideation phases, the process identified priority problems and explored realistic applications of AI technologies in education. The use of technology cards was particularly significant, facilitating design imagination by providing concrete insights into existing or hypothetical technologies and promoting a critical and informed reflection on AI's potential (van Amstel et al., 2012; Wölfel and Merritt, 2013). The technologies selected by the pilot groups, such as intelligent LMSs, adaptive virtual tutors, and multimodal assistants, not only address the needs identified by teachers but also align closely with evidence from international literature. For example, ITS has been recognised as an effective tool for personalising learning and supporting teachers in managing heterogeneous classes (Chounta et al., 2022). Similarly, the use of AI-based linguistic mediators, proposed to address language learning barriers, aligns with studies highlighting how translation and language recognition technologies can promote social inclusion and reduce educational inequalities (Iyer, 2019; Jiang, 2021). Integrating these technologies into school contexts represents an educational transformation strategy that goes beyond solving contingent problems, laying the foundation for a new vision of schools as laboratories of innovation and community resilience.

From a methodological perspective, a crucial aspect for future research is the need for scaling up the experimental approach adopted. The imagination lab conducted in the Italian pilot context offers a replicable model that could be extended to other small schools within the national network, creating an ecosystem of widespread experimentation. This process would not only validate the technologies and scenarios imagined but also identify specific technological clusters to address recurring problems. For example, further experimentation could explore the combined potential of ITS and multimodal assistants in multilingual contexts or the role of intelligent LMSs in ensuring educational continuity in areas affected by high teacher turnover. Additionally, we aim to scale up the lab and extend it to multiple pilot groups within the national network of small schools, leveraging a constantly updated clustering approach provided by the *Atlas of Small Schools* by Bartolini et al. (2023). Expanding the lab's reach could also generate comparative data that would support the development of a pedagogical

framework integrating DT, technological experimentation and active participation. This initiative would pave the way for scalable educational policies grounded on robust scientific evidence.

Extending this lab nationally and internationally could enable the development of a map of emerging technologies capable of responding to diverse educational scenarios. Future scientific research should focus on analysing the dynamics of implementing these technologies organised by problem scenarios in complex educational contexts, monitoring results, and proposing improvements based on empirical data. Building regional technology clusters, as suggested by Mangione et al. (2023), would be a crucial step in transitioning from experimentation to the realisation of scalable educational models that address local challenges while generating transferable knowledge to influence educational systems on a larger scale.

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