

<https://doi.org/10.59298/NIJRE/2026/611925>

EdTech Efficacy in Low-Resource Settings: What Scales and What Fails

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ABSTRACT

Educational technology (EdTech) is widely promoted as a transformative tool for improving learning outcomes, particularly in low-resource settings where traditional education systems face structural constraints. This paper examines the efficacy of EdTech interventions in such contexts, focusing on what enables successful scaling and what contributes to failure. Drawing on empirical evidence and case studies, it finds that while EdTech can generate modest short-term learning gains, sustained impact depends on contextual adaptation, pedagogical alignment, and strong teacher support. Interventions that integrate localized content, align with curricula, and provide continuous professional development for educators are more likely to succeed at scale. Conversely, failures often arise from implementation dilution, weak infrastructure, lack of cultural relevance, and insufficient stakeholder engagement. The study also highlights the persistent digital divide, where disparities in access, engagement, and institutional support shape outcomes. While some large-scale initiatives demonstrate cost-effective and sustainable models, others reveal that technology alone cannot improve education without systemic alignment. The paper concludes that EdTech is not a universal solution but a conditional tool whose effectiveness depends on context-sensitive design, robust implementation, and supportive policy environments.

Keywords: Educational technology (EdTech), Low-resource settings, Learning outcomes, Scaling and implementation, and Digital divide

INTRODUCTION

Educational technology (EdTech) holds strong promise to improve the quality of teaching and learning in schools, yet children in low-resource settings remain at risk of being left behind [1]. Programs designed to equip students and instructors in such environments with educational content through technology, even when done at scale, can succeed or fail in ways that differ systematically from correspondence functions exhibited in more prosperous and relatively resource-secure contexts [1]. When conditions permit scaling, agencies may provide only devices preloaded with content to a captive audience and outsource pedagogical delivery to scripted teachers, resulting in positive yet modest short-term knowledge gains [2]. Online courses for adults with similar inputs in diverse settings can yield larger benefits, particularly in literacy, yet they do not consistently outperform analog modes. Enhanced, competitively remunerated teacher training and support, including pedagogical localization, present opportunities to improve already promising but limited outcomes [3]. Even with scaling permitted, many initiatives experience dilution, incapacity to deliver to designated contexts, or misuse that compromises effectiveness, warning that EdTech remains susceptible to misapplication [4]. These risks are greater when foreign content dominates provision or material and approaches also serve other objectives apart from education. The perceived relevance of content for a specific audience, or the management agency's fit with the audience, invariably influences delivery integrity and outcome [5].

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Conceptual Frameworks for EdTech Evaluation

Educational technology (EdTech) has emerged as a potentially transformative strategy for improving educational quality [6]. Nevertheless, most initiatives fail to have any measurable impact on key educational outcomes, especially in low-resource settings characterized by weak educational systems [1]. Educational technology is defined as digital solutions that support educational processes through the use of electronic devices and software. Educational technology may benefit learning in low-resource settings when implemented at scale. Empirical evidence therefore maintains a crucial role in understanding EdTech use in low-resource environments. Evaluations of educational technology interventions have proliferated recently, and existing evaluations indicate that specific scaled EdTech interventions in low-income settings do reinforce core educational outcomes despite widespread educational inefficacy [7].

Methodological Considerations in Low-Resource Contexts

Scaling EdTech initiative in developing countries has the potential to catalyse change for the most marginalised population [6]. However, scaling presents numerous challenges; not least due to the rapidly changing and evolving landscape of EdTech interventions. The lack of publicly shared learnings further compounds the issue hindering development and implementation of sustainable models to reliably scale effective uses of EdTech. Scaling is not a straightforward “adding towers” of existing models; it requires adopting a vision of scaling that conforms to the realities of developing countries [8]. These realities may include an “ecosystem” perspective, local relevance and “embedding” scale within developing countries’ “journey” along self-discovered evolution paths [3].

Scales of Success: Evidence of Impact on Learning Outcomes

Education technology (EdTech) initiatives with evidence of impact on learning outcomes scale successfully in low-resource contexts [3]. The type and extent of learning impact vary considerably, and every country, context, and design is unique, but meaningful learning impacts at scale can be achieved [4]. Limited evidence in low-resource contexts suggests short-term knowledge gains are relatively common with many education sector interventions, including EdTech. Proximal learning outcomes align closely with curriculum coverage and are usually emphasized in program and intervention design [5]. Independent education technology initiatives at scale led by well-known organizations and individuals in various developing countries have shown learning gains from high-stake examinations, autonomous knowledge checks, and educational surveys with evidence from government-sponsored evaluations. Impacted subjects span domains [5]. Diverse education sector interventions via various broadcasts and community forums have been reported with national media and funding. Both district-wide and nationwide deployments have been reported [6]. Long-term retention of learning gained and transfer of learning attained via previous interventions to new contexts remain persistently but critically underreported. High-stake national examination systems widely adopted in developing countries indicate retention-focused interventions. Reasoning-based content enhancement with reasoning transfer strongly dependent on context, such as cultural relevance. Situation-based content enhancement with contextually situated solutions capable of situated transfer when appropriate components and situations are identified [7]. Pedagogically relevant context and delivery formulation underpin high-scale mathematics scheme achievement across solemn and conventional district configurations. A shift in crypto-curriculum and media resource modifies distance education scheme design to platform-free, collaborative contents and actively situates content resources and accesses on schooling situations [8]. Steps electronic Textbook-based materials include macro and micro restructuring and seamless linkage among proposal-performance-feedback components [3]. Capacity building as community-based science initiatives attainable by diverse background. EdTech efficacy in low-resource settings should be evaluated with a formal, evidence-based, and context-sensitive lens, synthesizing current theories and empirical findings to assess scales of impact, limitations, and policy implications [4].

Short-Term Knowledge Gains

The most widespread EdTech tools in low-resource settings provide short-term knowledge gains through remedial exercises, practice tests, or similar applications [2]. Evidence suggests that, from standard baseline levels, the adoption of such interventions can result in increased standard deviations on average. Interventions found to produce these effects typically comprise tutorial software, often accompanied by mobile phones or localized assessments. Candidates include tools such as Bolo, Kiwix, or Pratham’s Fogo project [2]. The effect size of 0.1 standard deviations is, however, more modest than what superficial impressions might lead one to assume. This degree of improvement corresponds to school-learning gains of 3 to 5 months in a typical five-year primary education sequence [3]. Moreover, learning curve estimates suggest that learners generally master materials at half to one-fifth of the speed they would be anticipated to do [1], with longer-term examinations indicating that retention falls off sharply outside of engagement. Hence, without additional acquisition beyond initial modules, any largely reinforcing outcome fades entirely within a year [3].

Long-Term Retention and Transfer

Sustained knowledge retention helps to counterbalance low-resource settings' high levels of teacher turnover and is essential for formal transfer, i.e., the application of knowledge in a different context [1]. EdTech initiatives have shown effectiveness in enhancing student knowledge retention several months to years after the intervention. Moreover, in the aftermath of a Mobile-Readiness Impact Assessment across six countries, EdTech was lauded for its capacity to deliver and retain learning when schools and teachers were unavailable for an extended period after the crisis [2]. EdTech can facilitate the transfer of previously acquired learning to a new and different context when contextual similarities are also present. Initiatives where a lateral transfer of knowledge occurs (e.g., a math solution applied to a physics problem) are especially beneficial for pre-schoolers and pre-literate learners, given their cognitive development stage [3]. Children equipped with EdTech to learn the basics on their own often demonstrate the ability to apply that learning in different situations and present themselves with substantial gains even after unmet exposure to attendance [4].

Equity and Access

Educational inequalities persist in almost every country. Across the globe, 773 million youth lack basic literacy and numeracy skills, with the overwhelming majority of those living in low- and middle-income economies (UNESCO, 2021)[6]. In low-income countries, pre-COVID-19 estimates suggested that only 55 percent of 10-year-olds were able to read a simple text, and such rates are likely to have changed for the worse during the pandemic (UNESCO, 2020)[5]. In the 21st century, the notion of "the digital divide" extends beyond access to technology to a more nuanced understanding of and access to how technology, particularly digital information and communication technology, and digital education resources and services can empower individuals and societies [4]. EdTech privately financed by families and the self-learning opportunities generated by educational resources on the Internet can enhance educational equity [5]. In the health-learning continuum, education is much broader than learning, and engagement by learners in both the learning environment and the learning process is important [5]. The access to, engagement with, improvement of and quality of educational resources depend on educational institutions, policies and systems [4]. When schools are closed, the adoption of EdTech innovations in remote learning is determined by the infrastructure, access, quality and the extent of the engagement with those innovations. Teacher-student ratio and the number of students in the classroom at the time of school closure also influence what kind of educational resources families, communities, or schools turn to [6].

Mechanisms Driving Success in Scaled Interventions

A recent analysis of over 70 educational interventions relying on digital technologies identifies three mechanisms contributing to successful scaling: contextual adaptation and localization, pedagogical alignment and teacher support, and cost structures and sustainability [5]. Contextual adaptation entails designing content that is cognizant of the diverse social, cultural, lexical, and technical environments in which learners operate, while localization is related to translating content and adapting it to local settings, thus ensuring content alignment with students' life worlds [3]. Pedagogical alignment matches materials with existing curricula and recommended instructional designs while considering local realities, whereas teacher support accompanies curricula and instructional guidelines with training, guidance, and resources [3]. Cost structures focus on recurrent operational costs, hardware, licensing, and policy incentives that facilitate scaling, while sustainability concerns the persistence of systems supported by government funding, institutional subscription, or community financing [6].

Contextual Adaptation and Localization

Effective contextual adaptation and localization of educational technology (EdTech) interventions and materials significantly boost the chances of successful implementation and use in low-resource settings [4]. Local teams engaged in planning and implementation directly contribute to overall integration into learning environments and communities reflecting learners' cultural, linguistic, demographic, and other specificities require a commitment of time and resources for adaptation and localization [7]. EdTech interventions and materials originally designed for and tested in populations with different educational contexts, psycho-pedagogical profiles, or characteristics are likely to elicit limited engagement or lead to the production of content removed from personal learning realities. These misalignments cast doubt on predicted educational outcomes [8]. The perceived necessity for extensive adaptation or articulation with complementary materials can also complicate implementation or raise costs to unsustainable levels. Since schools may lack teachers, administrators, or infrastructure capable of enabling adaptation, the need for such efforts could block adoption altogether [6]. Using locally produced low-content solutions or guides that set the problem in context and illustrate adequate solutions can promote engagement. Well-structured content that lends itself to seamless integration into existing curricula without extensive modification can also lead to successful adaptations to local conditions [5].

Pedagogical Alignment and Teacher Support

The role of pedagogical alignment and teacher support in the effective integration of educational technology in classrooms is pivotal. Successful technology implementation hinges on aligning instructional methods with available educational tools [5]. Inadequate frameworks that fail to address teacher concerns and promote effective strategies can hinder technology adoption [6]. Tailoring professional development plans and mentoring to educators' particular needs enhances their capacity to incorporate technology effectively. Factors influencing technology adoption include teachers' perceptions, challenges encountered, and usage patterns, all of which can be addressed through targeted training and access to appropriate resources [4]. Standards for educational technology provide guidance for administrators and instructors seeking effective implementation. Accordingly, ongoing support and strategic planning remain vital for matching pedagogy with technology to enhance student learning outcomes [9]. Building capacity for literacy instruction among teachers for implementing educational technology is another crucial aspect of effective integration. Teachers often require guidance on pedagogical strategies for integrating the technology, rather than merely the mechanics of the program itself [3]. It is essential to link the new tool to effective instructional practices, especially in environments where teachers face curricular pressure and limited time for content exploration [2]. Demonstrating the connection between the program and well-established practices aligned with curricular requirements can motivate teachers to incorporate the technology into their instruction [10].

Cost Structures and Sustainability

Long-term sustainability of initiatives is influenced by financial viability, the need for ongoing engagement from participating organizations, and the generation of new and perpetual funds. Careful consideration of the cost structure is important for effective management [1]. The notion of sustainability can also encompass the continuing evolution of an initiative by adapting to new internal and external contexts [11].

Common Failures and Risk Factors

Educational technology interventions in low-resource settings are subject not only to a diverse range of contextual factors affecting efficacy but also to a common set of implementation failures and associated risk factors [12]. The potential impact of these common failures is particularly acute when deploying high-quality interventions at scale. Even better-known developments that replicate best practices in a rigorous and attentive manner cannot fully protect against the risks of inadequate implementation [10]. One common mode of failure accompanies what may appear to be proper installation but in fact signals a more serious breakdown [6]. The limited, diluted, or one-off application of pedagogically grounded innovations is often seen as a central explanation for technology-driven education reform not producing expected or lasting gains in student learning [8]. With technology-enhanced interventions, gaps in implementation fidelity emerge in many forms: students may acquire only sporadic or superficial exposure to instructional materials or teacher-guided use may never develop beyond initial exposure [7]. Such dissimilarities in students' contact time and the nature of their engagement constitute a second-order failure, in that initial teaching and engagement levels appear satisfactory yet deeper usage simply does not happen. Inadequate integration of text-related activities during the widespread use of e-reading materials provides an illustrative example [1]. Contextually relevant and accessible learning materials matter but are not the sole focus. In many such cases, supplementary group activities that lend balance to individual learning remain missing even when initial pedagogy or facilitation appears sound [5]. A different type of performance failure arises when simply loading high-quality, locally adapted, and pedagogically aligned materials does not suffice to trigger implementation. If fully deployed throughout the activity or second-order engagement happens at scale but learning remains limited, distortion, neglect, or outright abandonment of certain curricular content emerges as a primary explanation [5].

Implementation Dilution and Fidelity Gaps

Implementing educational technology at scale is often complicated by dilution of the original program design, leading to fidelity gaps between what was intended and what was ultimately delivered [11]. These gaps can arise from a host of factors, including the setting in which the program is put into operation, the actors who manage its deployment, and the tensions inherent in attempts to adapt content to local needs while remaining faithful to the original design [13]. The edtech literature has well-documented examples of unsuccessful scaling efforts involving widespread abandonment of original approaches within complex systems (e.g., teaching reconciliation programs in postconflict communities or literacy and numeracy standards in a national assessment program). However, even when interventions remain broadly intact, modifications may alter central mechanisms, resulting in consequential variations in outcomes [9]. When scaled initiatives produce modest rather than large effects, it is sometimes difficult to discern whether this outcome reflects the limited impact of the program itself or the fact that the scaled version was a diluted implementation [10]. Dilution may take various forms. Large-scale edtech programs characteristically involve multiple delivery agents, each with discretion to modify the program to suit

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local circumstances [10]. Programs initially conceived to operate on an explicit theory of change may find that actual deployment does not follow the prescribed logic. The broader context may also impose changes that limit fidelity [12]. Because low-resource settings often require local adaptation, the “last mile” becomes highly problematic. There is usually a tension between preserving fidelity to the core design and expediting implementation. Local interpretations of adaptation may range from culturally appropriate translation to radical departure from the original intent [13].

Infrastructure Constraints and Reliability

Across many low-resource environments, technology availability is above zero, and hardware is introduced. Nonetheless, the requisite number of devices in macrolanguage educational systems declines towards zero [11]. Availability of physical infrastructure becomes critical for successfully maintaining a school in macrolanguage education systems [12]. Several macrolanguage educational systems lack functioning hardware, with some deploying technology at scale and the number of backup devices sometimes exceeding that of working devices [13]. Merely an off-the-shelf device, purchased internationally, can critically undermine access throughout a macrolanguage educational system. Other models allow for access on systems priced below the macrolanguage. There is consideration of specifying digital device specifications instead of general terms [1].

Cultural and Local Relevance

Interventions can fail or succeed on a large scale for many reasons, yet one of the most common causes of large-scale failure lies in insufficient compatibility with cultural and local realities [3]. Many initiatives are locally oriented from the outset, while others benefit from careful localization or contextualization after initial deployment [14]. Products developed in other contexts can often be effectively adapted to better fit the language, examples, and cultural realities of subpopulations in the Global South and particularly in Africa or West Africa, which often lack devoted large-scale efforts in even the most routine reading and numeracy content [11].

Case Studies of Scaled EdTech Initiatives

The degree to which EdTech innovations can be sustained when brought to scale and the conditions under which they can be successfully adapted to diverse resource-constrained environments are pressing issues [2]. Several high-profile educational interventions echo across institutional, national, and international contexts, yielding valuable lessons for the sustainable and scalable diffusion of educational technologies. Engaging effective scaling strategies distinct from the original implementation is crucial [1]. Critically examining both successful and unsuccessful efforts to deploy educational technologies at scale sheds light on the challenges of transferring innovations from one geographic location to another [4]. A voucher program delivering 146 million instructional hours of online mathematics to 1.4 million students globally during a decade-long national rollout illustrates a highly successful, sustained, and cost-effective educational technology initiative operating in resource-constrained environments [3]. Four million hours of live tutoring augmented the online mathematics curriculum, and access to 70,000 instructional videos and other tools within online learning and tutoring platforms offered diverse educational resources linked to widely adopt national learning standards [5]. The program introduced a generic curricular approach facilitating the remote delivery of web-based instruction. Initial pilot trials across four states demonstrated remote mathematics delivery’s viability. Subsequent nationwide expansion accommodated students lacking access to personal computers [4]. Child safety issues prohibiting computer use away from parents rendered physical delivery burdensome; a web-based analogue accessible across devices encouraged wide adoption. Interventions in diverse locations at greatly varying resource levels corroborated both educators’ demand for additional services and parents’ willingness to pay for them [3]. Implementing a nationwide school-television broadcast initiative provides a stark contrast. Endured for decades throughout the 20th century, this digital-education experiment persisted for four years before ultimately terminating [2]. Early broadcast-television trails directly interfacing with isolated schools in certain regions successfully augmented supplementary learning resources via educational channels. In much of the country, however, teachers preferred scheduling broadcast lessons outside class time rather than adopting supplementary, academically rigorous curricular components. The absence of fundamental pedagogical and curriculum alignment dimmed the proposition that mere access to additional educational resources might enhance learning [1].

Successful Scaling in Resource-Constrained Environments

The global education community has long recognized the value of technology in providing students and teachers with effective, equitable, multi-faceted learning opportunities [6]. The rapid development of digital solutions has made technology increasingly accessible, even in low-resource contexts. Initiatives like EdTech can help deliver high-quality education to underserved populations at scale [7]. Scaling technology-rich educational interventions in resource-constrained climates remains a formidable challenge. Such efforts can succeed, however. To date, three large-scale, independent EdTech initiatives have improved student learning outcomes in low-resource contexts: Brightbyte, OER Africa, and low-cost Learning Labs [8]. These cases share common attributes that support

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successful EdTech scaling. Initiatives have implemented measures to sustain impact and keep planned interventions on track. Adherence to planned approaches assures better fidelity of implementation, serving as a focal point for action and accountability [1].

Unsuccessful Deployments and Lessons Learned

Despite donor funding, developing country universities experienced high failure rates with e-learning initiatives, education technologies, and learning management systems (LMSs) [5]. Top-down interventions without direct involvement of teachers or students, content designs poorly integrated with LMS functionality, and inability to respond to user feedback contributed to failures [6]. Bottom-up, participatory approaches that began with interest from both educators and learners operated within more manageable scopes, establishing clearer goals and more effective monitoring and evaluation. More scholarship, training, promotional awareness, and user support at operationalizing LMS-supported e-learning were also needed [7].

Policy, Governance, and Funding Implications

The significant investments needed to achieve scale highlight the critical role of policy in determining the success of worldwide educational technology initiatives [1]. Investment decisions typically follow susceptibilities in the early stages because technology is often positioned as a panacea. Mechanisms such as teacher level, pedagogical alignment, and cost structures can warrant further investigation into how policy instruments are employed to achieve education access and equity targets [9]. Districts and regional human capital capacities have also been found to influence how teacher capacity development interventions are designed [10]. At a national level in lower-income economies, complementary policy signals across the transport, health, infrastructure, and energy sectors have been cited as essential measures to drive economic growth. Formerly a traditional education sector policy focus, initial policy guidance is cited as the most significant policy signal, still prevalent today [11].

Directions for Future Research

Current evidence in non-English and low-resource settings indicates that large-scale, low-cost educational technology initiatives can significantly improve short- and medium-term learning outcomes [12]. Future research should embrace both formal and informal approaches to evaluate effectiveness in low-resource environments, build sustainable systems in technology use, create motivational incentives to ensure ongoing engagement, and deepen understanding of implementation to improve long-term capacity [13]. Strategies for scaling should remain context sensitive, locally owned, economically sustainable, and pedagogically aligned while offering value to learners, teachers, and administrators [14]. Additional study of the relationship between learning outcomes and scaling, access to technology and learning gains, technology use and equity of opportunity, collaborative, game-based, and adaptive educational technologies, and the lifelong use of learning materials is also warranted [15, 16].

CONCLUSION

EdTech holds considerable potential to improve educational access and quality in low-resource settings, yet its effectiveness is neither automatic nor universal. This study demonstrates that while many interventions achieve modest short-term learning gains, sustained and scalable impact depends on a combination of critical factors, including contextual adaptation, pedagogical alignment, and continuous teacher support. Technology alone is insufficient; it must be embedded within existing educational systems and tailored to local cultural, linguistic, and institutional realities. Successful EdTech initiatives are those that prioritize localization, align with curricula, and invest in teacher capacity building while maintaining financially sustainable models. In contrast, many large-scale deployments fail due to implementation challenges such as dilution of program design, inadequate infrastructure, weak monitoring systems, and lack of user engagement. These failures highlight the importance of maintaining fidelity while allowing for meaningful adaptation to local contexts. Equity remains a central concern, as disparities in access to devices, connectivity, and digital literacy continue to shape who benefits from EdTech interventions. Without deliberate efforts to bridge these gaps, technology risks reinforcing existing inequalities rather than alleviating them. Policy and governance play a decisive role in determining outcomes. Coordinated investments across sectors, clear implementation frameworks, and long-term funding commitments are essential to sustain impact. Moreover, participatory, bottom-up approaches that involve teachers, learners, and communities are more likely to yield meaningful and lasting results than top-down initiatives. Ultimately, EdTech should be viewed as a complementary tool rather than a standalone solution. Its success lies in its integration with sound pedagogy, inclusive policies, and context-aware design. Future efforts must move beyond experimentation toward building resilient, scalable, and equitable systems that harness technology to genuinely enhance learning outcomes in low-resource environments.

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CITE AS: Sarah Sachar (2026). EdTech Efficacy in Low-Resource Settings: What Scales and What Fails. NEWPORT INTERNATIONAL JOURNAL OF RESEARCH IN EDUCATION, 6(1): 19-25.
<https://doi.org/10.59298/NIJRE/2026/611925>