International Journal of Educational Research Open 5 (2023) 100263

Contents lists available at ScienceDirect

International Journal of Educational Research Open

journal homepage: www.elsevier.com/locate/ijedro

Expert perspectives on how educational technology may support autonomous learning for remote out-of-school children in low-income contexts

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ARTICLE INFO

Keywords:
digital technologies
hand-held tablets
remote learning
Sub-Saharan Africa
autonomous learning
community support

ABSTRACT

Across Sub-Saharan African, 98 million children are illiterate and innumerate and do not attend school. Educational technologies (EdTech) that promote autonomous learning may ameliorate this learning poverty. Yet, little is known if or how these technologies can be implemented effectively within communities to support out-of-school children to learn basic literacy and numeracy skills. To address this knowledge gap, we explored expert perspectives of the perceived impact and challenges of implementing a unique large-scale EdTech learning competition conducted by the XPRIZE Foundation in 172 remote villages in Tanzania with 2500 out-of-school children. A qualitative expert elicitation was conducted with 14 key informants of the competition, using semi-structured interviews administered online over a 7-month period. Reflexive thematic analysis was used to analyse the data. Four key themes were generated: 'Technology as a novel concept', 'Children don't learn in a vacuum', 'Respecting the cultural context' and 'Accessibility problems in a mobile world'. Results demonstrated considerable community support throughout the competition, leading us to question the extent to which children can learn autonomously with EdTech alone. This study revealed communities are critical partners for the successful deployment of EdTech directly to communities in low-income settings, which has implications for organisations addressing the global learning crisis.

1. Introduction

Acquiring foundational literacy and numeracy is a basic human right, yet an estimated 330 million children of primary school age are unable to read and perform basic mathematics (UNESCO, 2019). This learning crisis was exacerbated further by the global COVID-19 pandemic, as 100 million more children are now thought to be under the minimum proficiency level for reading, with an estimated 70% of 10-year-olds unable to understand a simple written text (UNESCO, 2021; UNICEF, 2022a). This has disproportionately affected low-to-middle-income countries (LMICs), particularly in Sub-Saharan Africa, where traditional methods of education have been insufficient, and 98 million children do not attend school (UNESCO, 2022). This crisis urgently needs addressing as it perpetuates significant inequalities in access to and provision of quality education, costing governments upwards of $129 billion a year globally (UNESCO, 2019; The World Bank, 2019).

As traditional methods of education have failed to address the global learning crisis, innovative, alternative approaches are needed (The World Bank, 2018). One such approach is the use of mobile educational technology (EdTech) and interactive apps. There is an emerging evidence base supporting the potential of EdTech with interactive apps to provide access to high-quality education globally (Bettinger et al., 2020; Tauson & Stannard, 2018), with their use potentially guarding against learning loss in future pandemics (UNICEF, 2022b). Interactive apps can also promote autonomous learning, a valuable skill when using EdTech in large classrooms (Jordan et al., 2021) and a necessity when the learner is out of school and does not receive any formal support or instruction (Huntington et al., 2023). Thus, children in LMICs that are receiving poor or no education might benefit from a learning app intervention to acquire core foundational skills, but the effectiveness of learning technology remains under-researched and under-documented

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https://doi.org/10.1016/j.ijedro.2023.100263
Received 19 October 2022; Received in revised form 28 June 2023; Accepted 29 June 2023
Available online 8 July 2023

in out-of-school children, particularly in the context of Sub-Saharan Africa. As a result, it is unclear if and how EdTech might be deployed successfully directly to communities to promote the learning of foundational skills in out-of-school children.

To address this knowledge gap, this paper interrogates an EdTech intervention deployed directly to communities in Tanzania by exploring the potential of technology to support autonomous learning among out-of-school children in remote villages - a population who are deemed among those most at risk of experiencing the profound effects of learning poverty (Pitchford & Outhwaite, 2016; UNESCO, 2022). We provide empirical evidence on the perceived effectiveness of EdTech, specifically interactive apps, in supporting autonomous learning among out-of-school children in LMICs. Insights are generated into the potential of EdTech interventions to mitigate the effects of the learning crisis in Sub-Saharan Africa, particularly in remote villages. We further explore the challenges and opportunities associated with implementing these interventions, providing valuable information for stakeholders involved in educational policy and practice in these contexts.

1.1. Prior research on EdTech in low-income countries

Learning apps are presented as a promising solution to overcoming educational issues pertinent to the global learning crisis if they can be deployed successfully in LMICs (Bianchi et al., 2022; Major et al., 2021). Yet millions in developing nations remain omitted from such opportunities due to a lack of infrastructure (The World Bank, 2019). For investment in infrastructure to be realised, it is first necessary to demonstrate how educational apps can improve learning in LMICs and determine the conditions for successful implementation within school and out-of-school settings.

To date, most EdTech research has employed experimental studies to generate an evidence base measuring the effectiveness of learning apps within different populations, situations, and learning styles, which has been used to inform practice (Spieth et al., 2016). Randomised controlled trials (RCTs) have been conducted to study literacy and numeracy interventions and the efficacy of learning apps in LMICs implemented in the natural field of home, classroom, or community environments (e.g. Major & Francis, 2020; Haßler et al., 2016; Jordan et al., 2021). A comprehensive review of technology-based learning interventions surmises that studies have focused on developing children's understanding and educational attainment through gamification, app-based activities, work modules, and challenges, with the content mapped to an age-appropriate curriculum (Rodriguez-Segura, 2020). A recent meta-analysis demonstrated that technological interventions can produce significant improvements in attainment and learning outcomes for foundational skills compared to standard practice in LMICs, along with enhanced attitudes and motivation through app personalisation (Major et al., 2021; Jones et al., 2013). Improvements in learning outcomes for foundational skills have been evidenced in different LMICs in the Global South (Lurvink & Pitchford, 2023) and across different groups of learners, such as low and high achievers (Bardack et al., 2023), speakers of more than one language (Outhwaite et al., 2020), and children with special educational needs and disabilities (Pitchford et al., 2018; Lurvink & Pitchford, 2023).

In contrast, some studies report no effect of EdTech on language skills (e.g. Araya et al., 2019; Carrillo et al., 2011; Lai et al., 2013) and motivation (e.g. Ito et al., 2019) and suggest that EdTech can increase maths anxiety (Araya et al., 2019), which questions the efficacy of EdTech in raising learning outcomes. Furthermore, most EdTech research has been conducted within a school environment where teachers are available to scaffold and support children's learning as needed (e.g. Lurvink & Pitchford, 2023). A review of EdTech research suggests that self-led learning interventions are the most effective at raising learning outcomes, even within a school environment (Rodriguez-Segura, 2022). Autonomous learning is crucial for EdTech interventions with out-of-school children, as when no teacher is present to scaffold and support learning, the app technology needs to fulfil the role of the teacher. Research is needed that evidences the efficacy of EdTech in supporting autonomous learning with out-of-school children and determining factors that impact the successful deployment of learning apps directly within communities.

1.2. Autonomous learning for out-of-school children through EdTech

Educational apps promoting learner autonomy are arguably a pragmatic solution for facilitating learning for out-of-school children, where there is no access to traditional schooling, as the learning style is child-centred, and an experienced adult is not required to scaffold the learning process. Autonomous learning is a central feature of many educational apps, enabling the child to take control of their learning, supporting the management of what they learn and when, and engaging reflectively in the learning process (Lan, 2018; Huntington et al., 2023). Cultivating and encouraging learner autonomy may be critical to improving children's intrinsic motivation, sense of hope and agency, and educational outcomes and providing a different type of scaffolding for children with different or additional needs (Outhwaite et al., 2019; The World Bank, 2021).

Autonomous learning has garnered successful outcomes in low-income countries, such as Bangladesh when children could not attend school during the COVID-19 pandemic (The World Bank, 2021). This demonstrates that children can learn autonomously during prolonged disruption to school-based education. While there is emerging research on the provision of education for children unable to attend school due to the global pandemic, there has been little research on the effectiveness of EdTech interventions with children that do not typically attend school or have never accessed formal education, even when schools are operational. This may arise because this population is hard to access, as many out-of-school children live in remote villages. Yet, mobile games have been used in remote villages in Sudan, which resulted in sustained mathematics knowledge and motivation to learn (Stubbé et al., 2016), and autonomous use of a maths game was found to be more effective than no education, formal, or informal, education at the primary level (Stubbé et al., 2016). Furthermore, research in Ethiopia demonstrated that EdTech can foster the development of emerging literacy skills in out-of-school children and enhance children's motivation to learn (Gottwald et al., 2017).

This emerging evidence highlights the potential for educational apps to address the global learning crisis. Whilst some studies have shown positive gains start to diminish over time (Tauson & Stannard, 2018), assessments with a small sample of children in Ethiopia showed encouraging results for reading comprehension, word decoding and reading texts after one year (Gottwald et al., 2017). Clearly, further research is needed to identify and address factors influencing the sustainability of effective EdTech interventions with out-of-school children (Walton, 2018). It has been argued that while out-of-school children can learn autonomously, community members are crucial in facilitating and guiding children through the learning process, even if they are low-skilled, and predominantly for purposes of encouragement (Stubbé et al., 2016; The World Bank, 2021). Children in these contexts may lack the necessary experience and cognitive skills to achieve productive independent enquiry, so would strongly benefit from teaching and assistance in learning independently before being left to do so (Dean & Kuhn, 2007; Paradowski, 2015). For EdTech interventions to succeed with out-of-school children living in remote, low-income settings, implementers first need to establish if autonomous learning is possible; and if not, what solutions can be found to help scaffold children's learning with the resources available.

1.3. The Global Learning XPRIZE

This study aims to advance understanding of how autonomous learning can be achieved and sustained with out-of-school children from

low-income remote settings when given a tablet equipped with an educational app. It capitalises on knowledge acquired through a unique Global Learning XPRIZE competition (XPRIZE, 2019) that took place in remote regions of Tanzania, a country with over 1.4 million children recorded as being out-of-school (with the true figure likely to be much higher; Jordan et al., 2021). In partnership with the World Food Programme and UNESCO, teams were challenged to develop a scalable, tablet-based digital technology for marginalised children outside of traditional school settings to learn foundational skills. Five finalist teams were selected to field test their software with 2500 illiterate children, aged 9-11 years, from across 172 remote villages, most of whom had never attended school (XPRIZE, 2019). Villages were allocated as equally as possible across the five finalist teams, such that each team worked with 30 villages. There were also 22 control villages which received no tablets during the competition. Each village received the software only from their dedicated team, and allocations were made to assure a statistical balance of distribution, where possible, amongst age, gender, and proximity to the solar charging stations that XPRIZE installed to enable the tablets to be charged throughout the field trial and beyond.

Throughout the competition, there was very little direct involvement from XPRIZE and the finalist teams to encourage autonomous learning with the software. Within each village, there was a nominated village 'Mama' or 'Baba' who were paid a stipend to ensure children had the correct equipment to learn, including ensuring the solar station was working and maintained, children had working tablets, and no one stole the tablets. They were required not to direct or assist the learning process. The children were not given a schedule as to when or how often they should interact with the technology, instead they were left to direct and organise their own learning autonomously. The competition also employed local drivers to collect usage data from the charging points weekly, which was sent to XPRIZE. They also informed UNESCO and WFP of any technical support needed from the villages.

An independent evaluation conducted by RTI International assessed the impact of the software provided by the five finalist teams (King et al., 2019). Using standardised instruments (EGRA and EGMA), the literacy, numeracy, and writing skills of individual children participating in the field trial were assessed before implementation and again directly after the 15-month test period. Results indicated that solutions produced by KitKit School and onebillion achieved the greatest overall proficiency gains - although all teams demonstrated significant core improvements. Prior to the field test, 74% of the tested children never attended school, and 90% could not read any Swahili; these figures were halved at the end of the testing phase (XPRIZE, 2019). UNESCO also conducted a social-emotional assessment pre- and post-competition and found that, compared to controls, children who interacted with the software solutions showed improvements in many areas, such as self-esteem, self--expression, confidence, and independence (for more details, see Shukia et al., 2019).

1.4. Current study

The quantitative results of the Global Learning XPRIZE imply that educational apps deployed directly within remote villages can support autonomous learning. However, qualitative data regarding implementation was not gathered during the competition, so without knowing what happened on the ground, it is not possible to draw firm conclusions about interactive apps promoting autonomous learning. Further insights are needed from key informants of the competition to determine if additional factors might have influenced the successful implementation of the learning apps within the participating villages and ultimately the learning gains achieved. Post-intervention research can reliably inform long-term implementation and sustainability and provide insights into the general acceptability of an impact evaluation within the target audience (Pegrum et al., 2013), yet very few qualitative studies have been reported in this context for that purpose. To investigate factors contributing to the implementation process of educational apps deployed directly within remote villages for out-of-school children, we conducted an expert elicitation using semi-structured interviews with key informants of the Global Learning XPRIZE. Expert elicitations are a "structured approach for obtaining judgements from experts" (p.133), usually conducted about items or events of interest to inform best practices for policy makers (Verdolini et al., 2018). In this study, data generated from the semi-structured interviews were subjected to Thematic Analysis due to its highly flexible, impartial nature (Clarke & Braun, 2014). The experiences and perspectives of the 14 experts associated with the Global Learning XPRIZE were carefully analysed to generate core common themes.

Accordingly, this exploratory study investigated the following research questions:

1 How do experts associated with the Global Learning XPRIZE perceive the impact of EdTech in supporting autonomous learning in remote low-income settings?
2 What were the key challenges and opportunities identified by experts during the implementation of the Global Learning XPRIZE competition?

2. Method

2.1. Research Design

Semi-structured interviews were conducted to gather qualitative data on the experience and perspectives of 14 experts associated with the Global Learning XPRIZE. Semi-structured interviews with predetermined areas of focus afforded a valuable guiding framework for information elicitation without restricting the interview scope (Howitt, 2016). This interviewing technique allowed flexibility for both the researcher who may wish to probe further on points of interest and participants who may wish to discuss additional topics that they deem important to the research (Kallio et al., 2016). This adaptability also allowed for an informal, conversational style, interviewing enabling participants to discuss and share their experiences comfortably and openly (Bryman, 2016).

2.2. Ethics approval

Ethical approval was granted by the School of Psychology Ethics Committee at the University of Nottingham (ethics reference: s1247). Informed consent was obtained from all interviewees in line with the British Psychological Society guidelines.

2.3. Participant Recruitment

Interviewees were recruited using purposive and snowball sampling strategies (Robson, 2002). Initial interviewees were selected in collaboration with the Executive Director of the XPRIZE Foundation. Further interviewees were identified through snowball sampling when conducting interviews. Interviewees were asked by the researcher if there were any further individuals that they considered to be crucial to the competition. Recruitment ceased when all avenues had been exhausted, and the interviewees' suggestions were of individuals that had been interviewed previously.

2.4. Participants

Fourteen individuals that had key roles in the Global Learning XPRIZE participated in the study. Interviewees had a mean age of 46.77 years (SD = 10.45, range 33-68); there were nine males and four females. Eleven participants lived in the United States, one in Tanzania, and one in the Netherlands. One participant refused to disclose their demographics due to concerns about anonymity. Participants had

different job roles within the Global Learning XPRIZE, including senior members of staff from the XPRIZE Foundation, members of the finalist app teams, data analysts, judges of the competition, and individuals who directly oversaw the technological implementation on the ground. At least four participants spent direct time in the participating communities during the competition. Any other captured demographics are not reported to protect anonymity in a specific participant pool. Participation was voluntary; no incentives were offered for taking part.

2.5. Data Collection Procedure

Recruitment emails outlined the study aims and potential time commitments and provided a detailed information sheet. All interviewees were given access to the semi-structured interview protocol before the interview. Where possible, a rapport was established between the researcher and interviewee via email before the interview took place.

Data collection took place over seven consecutive months (May-December 2020) via online video platforms Zoom (n=13) and Skype (n=1). The average interview duration was 81 minutes, and each interview was audio recorded by the researcher following informed consent from the interviewee. To address the two research questions posed by this study, the semi-structured interview focused on the perceived impact of implementing EdTech in low-income settings to address the global learning crisis (RQ1) and the challenges faced with the implementation process during the competition (RQ2). Additional information was gathered on the interviewees' job roles and other demographics (see Participants) and their future dissemination plans.

2.6. Data Transformation

Audio data from each interview was recorded, encrypted, and stored securely on the researcher's computer before hand transcription. The transcription process is considered "a key phase of data analysis within interpretative qualitative methodology" (Bird, 2005, p227) due to early interpretations and meanings that might be conferred. Any personally identifying information was removed/de-identified, and participants were numbered for reference; a file containing the participants' identifying information was saved and stored separately.

2.7. Data analysis

Reflexive Thematic Analysis was conducted systematically using a six-stage process specified and revised by Braun and Clarke (2006; 2021). As this study was exploratory, an inductive approach was used in which no pre-assumptions or hypotheses were placed on the data based upon a particular theoretical stance. In line with the realist approach adopted in this analysis, themes were identified only at a semantic level (Braun & Clarke, 2013).

Transcripts were actively read and re-read numerous times by the researcher to become familiar with each account, and immersion in the data allowed initial analytic thoughts to develop. The second stage was to identify initial codes which applied across the data. Codes were used to label semantic or latent content within the data that was organised into meaningful groups (Maguire & Delahunt, 2017). These codes were then used to generate initial themes, which were reviewed and iterated upon throughout the analytical process. Developed themes were then refined, defined, and named appropriately in a manner that best captured the essence of what the theme conveyed before the final step of writing up the themes for dissemination.

The first author conducted all data analysis independently, in discussion with the co-authors. Coding reliability was not necessary as in reflexive Thematic Analysis, meaning and knowledge are understood as contextual, and the subjectivity of the researcher is considered a resource to develop the production of knowledge rather than a threat to credibility (Braun & Clarke, 2019).

2.8. Researcher characteristics and reflexivity

The first author is a doctoral researcher with a strong interest in educational development and prior university-based experience in pedagogical research and conducting qualitative research. The second and third authors are academics in educational technology research and data science for social good; both have published widely about marginalised communities in Africa. To ensure reflexivity, the researcher kept a journal of field notes throughout the interviews documenting their initial reactions, thoughts, and judgements (Trainor & Bundon, 2020). This process also included the mood and context of the interview, how the researcher had influenced the interview, initial interpretations, and anything further that could be incorporated into the interview schedule. The corresponding entries were examined when coding a transcript to provide further context and develop analytical understanding. While coding, further notes were made to record early interpretations and gradually develop coding decisions (Levitt, 2018).

3. Analysis & Preliminary Discussion

Four superordinate themes were generated from the experts' qualitative data that addressed how they perceived the impact of the EdTech deployed in the Global Learning XPRIZE competition in supporting autonomous learning (RQ1), and key challenges and opportunities that implementing EdTech directly to communities might afford (RQ2). These were: 'Technology as a novel concept', 'Children don't learn in a vacuum', 'Respecting the cultural context' and 'Accessibility problems in a mobile world'.

3.1. Theme 1: Technology as a novel concept

The first theme had two subthemes, 'Wariness of the unknown' and 'Interest in new digital tools', and they encompass the concept that tablet technology was novel to many children living in remote villages in Tanzania. Relevant extracts are highlighted in Table 1.

3.1.1. Subtheme 1a: Wariness of the unknown

Interviewees emphasized that early in the trial, apprehension was felt and voiced by villagers approached to take part, and who did not initially know of the XPRIZE Foundation or the purpose of the field trial (Q1). The misconception of XPRIZE being a freemason organisation was rationalised as a potential link to colonialism (Q2). Interviewees felt villagers were initially sceptical about a Western organisation (XPRIZE) coming with an unfamiliar solution to their problems. There were also general suspicions about the intentions of the competition and those running it, and the capability of tablets to act as surveillance devices (Q3). While interviewees highlighted this concern from villagers, they also explained why this was an understandable challenge within the trial, due to the innovations involved in modern technology (Q4). They described how the villagers justified the tablets' abilities with the explanation of witchcraft and tried to relate to this with their own amazement (Q5). Interviewees empathised with the villagers' difficulty acclimating to such a novel concept. Despite modern technology, such as tablets, being prevalent in Westernised cultures for approximately 40 years (since the widespread introduction of personal computers in the 1980s; Abbate, 1999), villagers felt wonder that such advanced options were possible and at their disposal for teaching and learning.

Interviewees also reported children in the competition had difficulty with the concept of tablet technology and how it functioned (Q6), which resulted in tablets being broken (Q7). Whilst the breakages seem like a negative event, interviewees insisted that this was not the case (Q8). Breakage was explained as natural curiosity in children to be encouraged and celebrated, as children thrive on such curiosity during learning (Flannagan & Rockenbaugh, 2010). These breakages represent a desire to learn and an inquisitive nature, and interviewees felt nurturing this was important as it was a great indicator of potential success for children

Table 1
Quotes to support Theme 1: Technology as a novel concept

Subtheme	Quote	Number
Wariness of the unknown	"There were some concerns from the villages around them thinking this project was associated with freemasonry and you know what are these tablets you're trying to bring into our village" (P14)	Q1
	"Knowing the history of colonialism in the area makes total sense in terms of what are these people and knowing it's a foreign country" (P7)	Q2
	"They were just very suspicious. Like what is this tablet gonna do again. Will the tablet listen to what's happening in the house, yeah, where's the sound going to you know? Is this a thing that spies on us? […] You know if you introduce something new and this is like a super new area to them, yeah people tend to step back. You have to be a really into your innovation type of chief to allow this to be happening in your village when you don't know what it involves." (P2)	Q3
	"They may have never seen a touch screen before, and you know all of a sudden they have a piece of glass which is talking to them in their own language." (P13)	Q4
	"There were questions in certain communities about witchcraft you know was this witchcraft were we trying to do something there were some rumours about it would steal the soul of your child. That one was widespread and like they've never seen it before I mean it is kind of witchcraft I don't know how a tablet works I'm like it seems magical that you can have something like that." (P7)	Q5
	"Some of these children had not even seen a smartphone before" (P14)	Q6
	"They were using these tablets. And they heard the voices. They heard voices inside a tablet, so they broke open the tablets 'cause they want to know where the voice was coming from." (P11)	Q7
	"If a kid is curious and they're opening up the tablet to find out what's in there then that's your future engineer that kid gets another tablet […] we really were like this is just a curious kid who wants to know and they're opening it up and maybe they want to build it, so we encouraged that kind of curiosity." (P7)	Q8
	"those problems really melted away in the first few months, there were very little of [them] by a quarter way through our field test." (P7).	Q9
Interest in new digital tools	"There were some jealousy issues the biggest issue we heard back was this family have two tablets and we have none and that kind of thing." (P7)	Q10
	"For the children, it was excitement. It was not just, you know as school, but it was a new gadget. It was fun, it does games or whatever." (P3)	Q11
	"They had things to share, they had things to tell, and their parents would say now I can talk with my child because they are so excited about the learning they have been doing and want to tell me about." (P3)	Q12
	"Some kids felt like they had already learned enough. They wanted something more." (P3)	Q13

benefitting from the intervention. Whilst there was clearly a prevalent theme of wariness at the intervention, presented in varying levels of mistrust and curiosity, interviewees stressed that these issues were not pervasive and were gradually overcome with time, patience, and perseverance (Q9), a situation not dissimilar to when technologies are integrated into classrooms in the US (Couse & Chen, 2010).

3.1.2. Subtheme 1b: Interest in new digital tools

Once children realised what was happening, there was a sense of excitement as they were empowered to learn with the technology. However, due to the selectiveness of the competition, with only children of a specific age being targeted to receive the tablets, some children felt left out (Q10). This jealousy indicates that the tablets may have been considered a desirable amenity to have within the family, either because they are a source of entertainment; or because they reflect a high-value possession that might elevate social status within the community - particularly if the community are coming together to help support children that have them. Many interviewees indicated that children were extremely excited by this new method of learning (Q11). This suggests that the excitement was not just because children were learning (sometimes for the first time) but because the tasks, games, and technology were new. Children liked getting involved in something so different from their usual setting and learning whilst having fun. That interviewees emphasised how excited children were over the intervention indicates that uptake and interest in mobile learning would be high in remote settings. The intervention also enhanced children's communication skills with their families, even when parents were not personally involved in the learning tasks (Q12). For the first time perhaps, children had information to relay in which they were the 'experts'; they could tell stories about their experiences and bond with their parents by teaching them things they had learnt. However, one interviewee admitted that for some children, interest waned over the 15-month trial period (Q13). This suggests that once tablets become familiar technology to children and the initial novelty has worn off, learning may become less interesting and engaging for children. However, the interviewees indicated that children wanted more, suggesting this was driven by a desire to learn.

3.2. Theme 2: Children don't learn in a vacuum

The second theme contained two subthemes, 'It takes a village to raise a child' and 'Simulating the teacher role', and they encapsulate the idea that children do not, and cannot, learn in a 'vacuum' by themselves. All interviewees emphasised that despite the XPRIZE competition presenting the notion of 'fully independent' learning, this was simply not feasible or realistic (Q14). This theme is supported by the quotes shown in Table 2.

3.2.1. Subtheme 2a: "It takes a village to raise a child"

The XPRIZE competition focused on facilitating autonomous learning wherever possible. However, a common theme within the interviewees' narrative was that there were many indications that considerable communal support was offered to children during the learning process. Despite the Mama or Baba in each village being told not to assist in learning, they became crucial support to children in the field trial (Q15). Different levels of support were witnessed (Q16), with most interviewees emphasising that the Mamas were generally very hands-on, and provided support, guidance, and motivation to children when they were unsure on what they were doing or just wanted someone to show their progress to. While not as focused as the support children might receive from a traditional teacher, the Mamas' support was reported as instrumental in instilling confidence in children and providing them with a safe non-parental space to bring any problems to. Interviewees emphasised that educational background was not important (Q17).

Other adults within the wider community were also keen to help children in any way they were capable, indicating the presence of social interaction and caregiver support, which can be important for children's development (Q18; Hirsh-Pasek et al, 2015). Interviewees explained that communities were willing to support children to have a safe working environment in which to learn with the tablets, whether this was by helping children create a specific place to work or by helping them to travel to charging stations. Interviewees emphasising that they had seen these forms of support with their "own eyes" emphasized the importance/pride they placed in such activities – and their expression of that support as an important personal account, that needs to be communicated and believed, was capturing the essence of what the community experienced during the competition.

Table 2
Quotes to support Theme 2: Children don't learn in a vacuum

Subtheme	Quote	Number
-	"I've seen work that says they can just pick up a tablet and start using it tomorrow you know, and we know that's not true." (P1)	Q14
It takes a village to raise a child	"The village Mama became very important. They will talk to them in a way that is not parental, it is one of an adult, who is an educator, just not in the traditional sense." (P3)	Q15
	"There was obviously a different level of the sort of support that the village Mamas provided, you could almost say some did their job and went home essentially and some sort of went the extra mile to support the children with some of the apps and stuff." (P2)	Q16
	"There was obviously a different level of the sort of support that the village Mamas provided, you could almost say some did their job and went home essentially and some sort of went the extra mile to support the children with some of the apps and stuff." (P2)	Q17
	"I've seen it with my own eyes like a lady opened up her shop and in the shop is nothing more than a table and a tent. And that is it and she would open it up for the kids so they could sit there or they would sit on the tree." (P2)	Q18
	"People would gather round erm but usually the kid that would have the tablet in most communities we saw even though we would maybe share it they wouldn't let other kids touch it they would be like I'll do the, you know, controls." (P7)	Q19
	"I did see kids setting up their own school, they would gather together under a big tree and meet at a certain point. It wasn't just siblings, it was a group of kids, and they were like 8 or 9 taking turns with the tablets and erm, yeah, there were several instances of that, and you know if they had a very active village Mama then she would you know, like encourage them too." (P2)	Q20
Simulating the teacher role	"We rely on that idea that all children will love to explore freely too much. And we didn't know that some children actually had been trained to follow the instructions very strongly from early days. Our idea actually gave too much freedom for many learners who have never previously had a chance to explore themselves. […] If we did it again, we may make it more instructional." (P5)	Q21
	"It's certainly possible that the kids in our app went through the content just exploring it without really knowing what they were doing. Or maybe you know, maybe exhausted some of the content too quickly without fully digesting it." (P11)	Q22
	"There is a tendency of children to choose easy problems that they're going to get 100% correct and how do you navigate that in these informal learning environments where there isn't a teacher to push them harder and get them on that track." (P1)	Q23
	"What is needed is more support and I think motivation to engage in some of the other types of activities that they might find more challenging" (P8).	Q24
	"The [avatar] kind of mimics what the child's experience would be in a good school where they would get a lot of attention, so there's a teacher character. There's praise, there is guidance and structure, you know, there's repetition, there's practice, there's remedial work." (P13)	Q25
	"That feedback and sense of progress are really important. […] Do that in a way that encourages persistence, and while building a sense of self-efficacy and giving people a sense of progress." (P6)	Q26

Guidance from adults within the community was not the only support that interviewees reported. Children gathered in groups to play on the tablet together, suggesting that peer learning was important to them even when not enforced (Q19). The dominance over being in control of the device demonstrates feelings of possession and attachment to the tablet, with children considering the tablet theirs to share as they saw fit - rather than a commonly shared unit. Despite this, groups of children developed informal schools to facilitate shared learning (Q20). The tendency for a lot of children throughout the competition to "create a tablet school" (P7) indicates that despite having no formal learning context, children enjoyed a broader learning environment and orchestrated themselves to facilitate sharing and group learning. Seemingly, buildings and physical provisions are less important than the atmosphere and quality of group dynamics that supports and guides children to develop their abilities. This also allows the "child to teach [other children], which helps a child learn even better" (P3).

3.2.2. *Subtheme 2b: Simulating the teacher role*

The XPRIZE competition did not dictate the design or content of the software to participating teams, nor how to best encourage children to engage. This was a subject of much discussion, with interviewees emphasising the importance of balancing instruction and offering free choice "for feelings of autonomy" (P1). Some interviewees stressed that their teams initially felt they had miscalculated the amount of freedom that should be given to children - and perhaps had even conferred too much choice throughout the learning process (Q21). Interviewees suggested that the local culture instilled a sense of obedience in children, and while this was something that children were familiar with and comfortable with, it constrained exploration and self-directed learning. Some interviewees expressed the desire to improve upon this in the future, and others felt the high level of freedom negatively impacted the software solution's longevity (Q22). Interviewees also talked about the freedom provided by giving children more of a 'browsing opportunity' and worried that this may have distracted them from fully investing in the content as they would have hoped, as no one was telling them they had to do it. Interviewees considered the reasons that adding structure could benefit learners in out-of-school environments (Q23).

The idea of the teacher as the 'motivator' of children, and this element being absent in the software design, highlights one of the problems that participants felt was potentially prevalent within EdTech learning interventions in general (Q24). Although the interventions analysed in this study were heavily focused on autonomous learning, this was often at odds with what interviewees believed to be key to good practice in education. However, interviewees were aware of the context the competition was situated in, which lacked the option of teachers or formal schooling, with some teams actively attempting to address this by adding a teacher figure to their software – aiming to further motivate children and guide them appropriately through the content (Q25). Teams that included an avatar figure stressed the importance of giving children structured guidance that would benefit them most, aiming to help maintain learners' interest while they progressed through the software at a pace suitable for themselves and one reflective of a classroom environment (Q26). Interviewees reported that to really fill the gap produced by the lack of a classroom, personalised and task-specific feedback needed to be given to encourage children not to give up, particularly with challenging tasks.

3.3. *Theme 3: Respecting the cultural context*

The third theme focused on the importance of respecting the cultural context to maximise success and avoid causing offence or risking failure based on a lack of contextual understanding. Table 3 shows supporting evidence for this concept.

All interviewees emphasised the importance of being "confident of what opportunities there are for these learners in their environment" (P1) before creating the software and personalising it to the community

Table 3
Quotes to support Theme 3: Respecting the cultural context

Quote	Number
"We understood the home environment where children are exposed to a lot of language, but there's no culture of reading so we understand where the child was at. We could have gone with a whizzy design with lots of sounds and colours and so on, and that has its place, but not in a context where children just aren't used to that sort of stuff. It needs to be as simple as possible and focus on the needs of the marginalised child."(P13)	Q27
"They often don't have the right cultural references to make them relevant to the particular learners, and that is an artefact of bringing in a bunch of content and games and things that have been successful elsewhere, so that's great, but erm you know successful for whom and in what context? So uh you know there's this race car game for kids who have very rarely even seen a car." (P1)	Q28
"We got some feedback as to like you know, why is this character doing this? Or you know this character doesn't seem to be a pleasant one or a fun one, which we thought they were. I think in one game we had an owl or something like that and then the feedback we got was that you know that is probably not appropriate as the owl has more negative connotations in Africa." (P9)	Q29

Table 4
Quotes to support Theme 4: Accessibility problems in a mobile world

Quote	Number
"Some kids were small, and the charging station will be like over 3km and the kid can't walk with this gadget by herself to go charge it." (P3)	Q30
"There was one village where the kids had to go through an elephant area to get to the station. […] People were killed by the elephants, so those kids didn't dare to go to their charging station because they were afraid of the elephants." (P2)	Q31
"I love the thought of having a district bus decorated as a school and where kids can go with their tablets twice a week so they don't have to walk 10 miles, but the bus comes to them – that would be something and a possible solution." (P2)	Q32
"We made it so the tablets couldn't be used past 10pm. Households probably didn't have electricity, or another source of light so will play an app that just creates light so people can do other tasks, running down the battery and potentially not achieving much in terms of children learning." (P13)	Q33
"The tablets could break because they got water splashes on them or dust, or they were shaken or used too roughly" (P10).	Q34
"When it has run into problems, then you can't take advantage of industry to repair it because no-one's seen one before, there's no screen replacement that can happen on a local basis and so on and so forth um whereas you know, there are mobile phone dealers and technicians that are er you know more spread out around the country." (P1)	Q35

of focus (Q27). The five finalists had various levels of previous experience with marginalised children, and children in Africa, so began the competition with differing levels of understanding and knowledge of the context they were working in. Some teams decided to keep things simple to avoid overwhelming the child with a novel environment and focus on making children aware of exactly what was happening within app flows. This highlighted a clear goal for some; understanding that children were already facing a novel situation simply engaging with the tablet hardware, there was increased motivation to keep other elements of the learning experience as basic and straightforward as possible. Other teams felt more confident about gamifying elements of the software and making them a challenge; yet others focused on producing tasks with rewards, hoping to keep children as invested as possible given their limited previous exposure to gaming technology. However, this came with its own identified challenges in transferring pre-existing game mechanisms to this new context (Q28). While for cost and time purposes, it can be helpful to exploit games that already exist (and have been shown to be successful in other contexts) interviewees stressed that using unfamiliar objects was not conducive to learning outcomes. One interviewee reported a hurdle their team faced was based on an avatar/character used in the software and the impact it had on children in remote villages in Tanzania (Q29), again demonstrating the importance of understanding the cultural context in which educational technology is to be deployed.

3.4. Theme 4: Accessibility problems in a mobile world

The fourth theme concerned accessibility problems during the competition that had an impact on children's ability to learn, as evidenced in Table 4.

Whilst many infrastructural challenges were foreseen by the XPRIZE team and addressed wherever possible, some difficulties remained, for example, the geographical locations of the charging points for the tablets. Some villages were extremely remote so charging points were not within a convenient proximity (Q30). Charging stations were planned to be as accessible as possible, but due to the remoteness of some villages this was not always possible so imposed a significant physical and logistical strain on children and their families. Children's families also needed to see the value in learning with the technology, as families were burdened with organising visits to the charging stations when they were too hard to be accessed by the children alone. Interviewees, however, emphasised that villagers still made the effort to charge the tablets even when charging stations were far away, demonstrating a high level of interest in supporting learning with the technology.

There were not only physical limitations for children but sometimes additional safety challenges (Q31). This emphasises the importance of carefully planning infrastructure and demonstrates the benefits of detailed local knowledge, with different villages having different environments, routines, and surroundings that could impact on the success of using tablets in the community. Interviewees felt infrastructure was a problem that would be extremely difficult to overcome in rural locations, but some had started to think of potential solutions (Q32). However, the extreme lack of accessibility of some villages (with no clear paths or roads) may limit such solutions. Another interviewee explained that they knew it was impossible to change the competition's fundamental infrastructure, so they tried to adapt their software to fit the context (Q33). This would allow battery life to last longer and therefore reduce the frequency of trips to charging stations, limiting risk to children.

Another challenge raised was the fragility of the hardware itself, especially when not cared for effectively or kept in harsh conditions (Q34). Children were not familiar with looking after hardware of this nature, and despite being guided on how to do so, tablets often broke for practical reasons rather than out of curiosity as explored previously. This defines a further accessibility problem, not only due to hardware costs but also to long-term technology maintenance in areas that are unfamiliar with tablets (Q35). Even if funds were made available, interviewees stressed that knowledge and equipment was not currently available *in situ* to maintain a large-scale, ambitious undertaking of providing out-of-school children with tablet learning.

4. Discussion

This study explored expert perceptions of how EdTech might support autonomous learning with out-of-school children in remote settings in LMICs, and the challenges and opportunities that deploying EdTech within this context might afford. To achieve these aims, an expert elicitation was conducted with key informants from the Global Learning XPRIZE competition to garner on-the-ground experiences to determine if the learning outcomes achieved throughout the competition could be attributed purely to autonomous app-based learning. Four themes were identified that highlight a high level of community engagement in supporting the implementation and continuity of the EdTech intervention throughout the XPRIZE competition. Clearly, this challenges any inferences from the quantitative results from the Global Learning XPRIZE competition that might indicate children can learn autonomously purely with interactive apps.

4.1. Technology as a novel concept

The first sub-theme showcased the associated confusion and problems caused by the novelty of the technology. Villagers were concerned about XPRIZE being a freemasonry, perhaps due to the documented chequered history of English and American colonialism in East Africa (Bulhan, 2015). This may explain why villagers were left feeling uncertain and wary about the involvement of XPRIZE if they were "sinister forces" that could be "plotting against the country" (The Economist, 2018, para.1). The further emphasis on spying suggests feelings of an insider/outsider divide and mistrust in newcomers introducing new technology that villagers had never experienced before. Belief in witchcraft has been perpetuated in many modern African cultures, particularly in circumstances where rational knowledge fails to explain an event or phenomenon, such as the existence of diseases with mysterious causes (Lewis, 2021). The novelty of something so new, different, and with no apparent rational explanation to the villagers may be why some initial attributions to witchcraft were made. This sub-theme highlights the importance of sensitization prior to introducing a technology intervention in low-income countries. The sensitization process should be gradual, thorough, and contextually bound for maximum success, with villagers being given the opportunity to explore any questions with experts.

The second subtheme demonstrated children's interest and excitement about learning with the tablet technology. This corroborates previous research on the use of EdTech for children in displaced settings, in which increased engagement, motivation and excitement are some positive findings (Islam & Grönlund, 2016). Our study revealed valuable shared parent-child experiences that would likely consolidate learning for the child, as well as their visible excitement demonstrating the value of learning for their parents. EdTech has previously been shown to strengthen the bond and social interactions between parent and child, both during the COVID-19 pandemic and in multiple low-income emergency settings, as more opportunities to share and demonstrate new skills are experienced, allowing parents to further engage with their learning (Wang et al., 2020; Power et al., 2021).

Despite high levels of interest and excitement driving the use of tablets through the competition, it remains to be determined if this interest will be sustained long-term. Levels of interest in learning with the tablet technology decreased over the 15-month test period, and this has also been reflected in Western settings, where tablet use was initially preferred to 'traditional' learning methods but with interest waning following sustained use (Baytak et al., 2011; Muhammad et al., 2019). Motivation has also been shown to wane in children in developing countries over time as familiarity with technology develops and warns that the novelty of tablets is a temporary motivator that is not sustained (Gulati, 2008; Tamim et al., 2015). However, in remote environments where there are no other opportunities to learn, tablet use may continue long-term as this is the only viable option available to children. This possibility remains to be determined.

4.2. Children don't learn in a vacuum

The first sub-theme emphasised the extent to which families and the wider community supported children's learning experience. Despite no formal instructions to get involved, the choice that some village Mamas and community members made to go the extra mile shows they valued children's learning and would work hard to support this. Emotional support and scaffolding are crucial for a child to progress and ensure that learning is productive, whilst reinforcing social interaction is needed for a positive learning experience (Hsin et al., 2014; Tauson & Stannard, 2018). Partnerships with family and community have previously been shown to positively influence children's learning in Tanzanian school settings (Byerengo & Onyango, 2021), so it is possible that establishing community-level partnerships could have a similar influence in out-of-school settings.

Children were also shown to receive support from peers. This is significant as peer learning can be crucial for children's early learning development, as it fosters collaborative learning, the development of meaningful social interaction, and enhances core cognitive skills (Garris et al., 2018). The creation of informal 'schools' or learning areas led some children to take on the teacher role, which is a common phenomenon when learners are given freedom and facilitates the teaching of new techniques to other children. This can, in turn, consolidate teaching-child learning and understanding. For out-of-school children lacking formal tutoring, such peer interaction could be highly beneficial (Tauson & Stannard, 2018).

Together, these results indicate that a fundamental contributor to the success of the Global Learning field trial was communities banding together to support children, practically and emotionally, despite many having never experienced formal education.

The second sub-theme showed that having an in-app avatar is important for out-of-school children who do not have access to a formal teacher (see also Huntington et al., 2023). Some teams chose to provide children with lots of freedom, as previous research on autonomous learning has shown that children choose the most interesting, easiest, and most enjoyable tasks in the short term rather than tasks that will challenge them educationally (Couse & Chen, 2010). It has been argued that choice-based learning should remain integral, given the evidence children often learn best when selecting their own activity, direction, and pace (Chad-Friedman et al., 2019). However, Hirsh-Pasek et al. (2015) argued that an educational app should require thought, attention, and intellectual effort by the child, and interviewees agreed that the lack of structured guidance could be problematic for children's progress. Our study confirmed that in this context, the presence of an in-app avatar was a motivating influence and guide for children (Kolak et al., 2021). Major et al. (2021) emphasized the value of personalisation within EdTech, to facilitate a learning experience driven by children's interests and needs, with support tailored as appropriate. The use of personalized feedback in EdTech significantly increases children's self-efficacy in learning, which is a key component for improving learning outcomes (Mouza & Cavalier, 2013; Outhwaite et al., 2023). Despite this, it has also been argued that scaffolding within educational apps is possible using feedback, learning in such remote environments may require conceptual feedback that engages children in far more complex, evaluative thinking (Cayton-Hodges et al., 2015). However, in a setting where literacy levels are extremely low for adults, as with the remote villages in the XPRIZE competition, this level of sophisticated scaffolding would most likely not be feasible from within the community.

Whilst autonomous learning was an ideological goal of the XPRIZE competition, interviewees noted challenges to free learning and emphasised the need to balance autonomy with directed progression through an educational app for it to be deployed successfully with out-of-school children.

4.3. Respecting the cultural context

The third theme centred around knowing and respecting the cultural context in which the intervention was to be implemented (Keengwee & Bhargava, 2013). A lack of developer knowledge of the cultural context was shown by some teams, illustrating practical challenges due to the negative impact of a game, character, or other elements within the app. Hirsh-Pasek et al. (2015) highlighted the need for app content to be culturally sensitive and potential problems when app content is not fully cognisant culturally. Children may be more likely to engage in culturally appropriate content than content not aligned with their context (Hsin et al., 2014). This will constrain scalability and challenges the notion that once shown to be successful, an app can be deployed as a global learning tool (XPRIZE, 2019). However, novelty *per se* might not be problematic, as children demonstrate an interest in games that include unfamiliar objects or scenarios (such as space explorations and

imaginary play; Fleer, 2015; Suminar & Wardana, 2018). This suggests that app developers should consider the cultural context carefully when designing content and structure, ideally in consultation with communities that will receive the intervention, to ensure the longevity of use.

4.4. Accessibility problems in a mobile world

The fourth theme concerned accessibility with the mobile technology used in the remote villages of Tanzania, despite there being 4.32 billion mobile internet users globally (Statista, 2021). Several infrastructural challenges were addressed prior to the competition, but issues commonly cited for mobile technology interventions in developing countries remained, primarily the distance to the charging stations and the safety of the children walking to them (Camfield et al., 2007; Crompton et al., 2021). Previous technology interventions have attempted to circumvent accessibility issues by providing tablets that have an inbuilt solar panel. While this raises the cost of interventions, it lowers threats to safety and helps avoid logistical issues (Moss, 2020). Crompton et al. (2021) considered digital access a fundamental barrier to equal education opportunities. Our study revealed that the community was crucial in helping children access EdTech for learning.

Tablets were also shown to be utilised for other purposes, which is common in low-income contexts (Tauson & Stannard, 2018). For example, tablets were used for lighting in the evenings, which drained the battery and prevented children from accessing the learning apps. Another issue was hardware fragility, which is problematic in low-income, remote areas, as breakages incur high outlay and ongoing replacement costs over time. The cost of hardware has been shown to be one of the greatest barriers to EdTech solutions to learning in low-income countries, with governments showing a preference to spend on tangible assets, such as building schools and hiring teachers (Passey et al., 2016; Kaguo, 2011). Governments wanting to take advantage of digital technologies must consider how maintenance can be handled locally to maximise sustainability.

4.5. Limitations

A potential limitation of this study is the interviewees' investment in the success of the competition. There is the risk that some interviewees were more likely to maximise their successes and hide failures, as is common when reporting results in learning and teaching research (Dawson & Dawson, 2018). While interviewees' attitudes may be more positive than outsiders, results demonstrated that several challenges were identified by the interviewees. Being realistic about successes and barriers is key to developing best practices and making firm pedagogical advances in the field (McCormack et al., 2013).

It is also important to consider the role of the expert. The experts were chosen based on their role within the competition, how involved they were, what they could tell us about the process and their expertise. However, the children and the communities involved in the competition could also be considered experts. Most interviewees mentioned the desire to have access to data exploring village attitudes and continued use of the tablets, labelling this 'valuable' and 'critical'. This data would be difficult to collect *post hoc* following the competition due to the geographical remoteness and language barriers involved. Employing a mixed methods approach within the original research design would have been preferable.

5. Conclusion and Future Directions

This study has highlighted the importance and extent of community engagement in supporting different aspects of the implementation of an EdTech intervention with out-of-school children living in remote regions of Tanzania. We have shown that app-based instruction can successfully support foundational learning with out-of-school children but that EdTech alone seems insufficient to support the learning process as high levels of community support and engagement were required. This result challenges claims that EdTech pedagogy can promote autonomous learning without the need of adult support and demonstrates that for pedagogical practice with EdTech to be effective and sustainable in LMICs for out-of-school children, engagement with communities is essential. Our results have clear implications for practice as they emphasized the need for a thorough sensitisation process to ensure that villagers felt comfortable with the technology as it was being introduced into their community. Furthermore, engaging community members in the design process of educational apps might be beneficial to ensure content is culturally appropriate. Governments, implementers, and app developers should consider community members as critical partners in designing, deploying, and scaling educational technology interventions in remote, low-income settings to maximise overall success and sustainability. Given the global commitment to achieve the Sustainable Development Goal for Education by 2030 and ensure inclusive, equitable, quality education for all (UNDP, 2023), the insights gleaned from this study should be particularly informative to global educational organisations when implementing EdTech interventions with the world's most marginalised children.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

This work was undertaken as part of a doctoral research programme in collaboration with the XPRIZE Foundation. The XPRIZE Foundation facilitated access to key informants, as described in the Methods section of the report, and participated in the study as key informants, but otherwise did not influence the research design, data acquisition process, data analysis, or interpretation of research findings. Accordingly, all authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Acknowledgements and Funding

We wish to thank the 14 key informants who gave up their time to participate in this study. This work was supported by the XPRIZE Foundation and the Economic and Social Research Council [grant number ES/J500100/1].

References

Abbate, J. (1999). Getting small: a short history of the personal computer. *Proceedings of the IEEE, 87*(9), 1695–1698. https://doi.org/10.1109/5.784256

Araya, R., Arias Ortiz, E., Bottan, N. L., & Cristia, J. P. (2019). Does Gamification in Education Work?: Experimental Evidence from Chile. *Inter-American Development Bank*. https://doi.org/10.18235/0001777

Bardack, S., Lopez, C., Levesque, K., Chigeda, A., & Winiko, S. (2023). An exploratory analysis of divergent patterns in reading progression during a tablet-based literacy program. *Frontiers in Education, 8*, Article 983349. https://doi.org/10.3389/feduc.2023.983349

Baytak, A., Tarman, B., & Ayas, C. (2011). Experiencing technology integration in education: children's perceptions. *International Electronic Journal of Elementary Education, 3*(2), 139–151.

Bettinger, E., Fairlie, R. W., Kapuza, A., Kardanova, E., Loyalka, P. K., & Zakharov, A. (2020). Does EdTech substitute for traditional learning? Experimental estimates of the educational production function. *NBER Working Paper. National Bureau of Economic Research*.

Bianchi, N., Lu, Y., & Song, H. (2022). The effect of computer-assisted learning on students' long-term development. *Journal of Development Economics, 158*, Article 102919.

Bird, C. M. (2005). How I stopped dreading and learned to love transcription. *Qualitative Inquiry, 11*(2), 226–248. https://doi.org/10.1177/1077800404273413

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health, 11*(4), 589–597. https://doi.org/10.1080/2159676X.2019.1628806

Braun, V., & Clarke, V. (2013). *Successful Qualitative Research: A Practical Guide for Beginners*. London: Sage.

Braun, V., & Clarke, V. (2021). Thematic Analysis. *Analysing Qualitative Data in Psychology* (pp. 128–147). SAGE Publications. https://doi.org/10.4135/9781446207536

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Bryman, A. (2016). *Social research methods*. Oxford University Press.

Bulhan, H. A. (2015). Stages of colonialism in Africa: From occupation of land to occupation of being. *Journal of Social and Political Psychology, 3*, 239–256. https://doi.org/10.5964/jspp.v3i1.143

Byerengo, V. P., & Onyango, D. O. (2021). School-Family-Community Partnerships and Their Influence on Student Achievement in Public Secondary Schools in Ilemela Municipality, Tanzania. *Handbook of Research on Nurturing Industrial Economy for Africa's Development* (pp. 357–379). IGI Global.

Camfield, J., Kobulsky, A., Paris, J., & Vonortas, N. (2007). A report card for one laptop per child. *Closing the Digital Divide via ICTs and Education: Successes and Failures*. joncamfield com/writing/Camfield_Report_Card_for_OLPC.pdf.

Carrillo, P. E., Onofa, M., & Ponce, J. (2011). Information Technology and Student Achievement: Evidence from a Randomized Experiment in Ecuador. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1818756

Cayton-Hodges, G. A., Feng, G., & Pan, X. (2015). Tablet Based Math Assessment: What Can We Learn from Math Apps? *Journal of Educational Technology & Society, 18*(2), 3–20.

Chad-Friedman, E., Lee, Y., Liu, X., & Watson, M. W. (2019). The effects of visual arts pedagogies on children's intrinsic motivation, creativity, artistic skill, and realistic drawing ability. *The Journal of Creative Behavior, 53*(4), 482–495. https://doi.org/10.1002/jocb.228

Clarke, V., & Braun, V. (2014). Thematic analysis. In A. C. Michalos (Ed.), *Encyclopaedia of Quality of Life and Well-Being Research* (pp. 6626–6628). Dordrecht, Netherlands: Springer. https://doi.org/10.1108/RR-06-2015-0143.

Couse, L. J., & Chen, D. W. (2010). A tablet computer for young children? Exploring its viability for early childhood education. *Journal of Research on Technology in Education, 43*(1), 75–96. https://doi.org/10.1080/15391523.2010.10782562

Crompton, H., Chigona, A., Jordan, K., & Myers, C. (2021). Inequalities in Girls' Learning Opportunities via EdTech: Addressing the Challenge of Covid-19. *Zenodo*. https://doi.org/10.5281/ZENODO.4917252

Dawson, P., & Dawson, S. L. (2018). Sharing successes and hiding failures: 'reporting bias' in learning and teaching research. *Studies in Higher Education, 43*(8), 1405–1416. https://doi.org/10.1080/03075079.2016.1258052

Dean, D., & Kuhn, D. (2007). Direct instruction vs. discovery: The long view. *Science Education, 91*(3), 384–397. https://doi.org/10.1002/sce.20194

Flannagan, J. S., & Rockenbaugh, L. (2010). Teaching inquisitive young children how to ask good questions. *Science and Children, 48*(4), 28–31.

Fleer, M. (2015). Pedagogical positioning in play–teachers being inside and outside of children's imaginary play. *Early Child Development and Care, 185*(11-12), 1801–1814. https://doi.org/10.1080/03004430.2015.1028393

Garris, W. R., Lester, L., Doran, E., Lowery, A., & Weber, A. (2018). iCollaborate or Not: Does Technology Impede Collaborative Learning among Primary Grade Students? *International Journal of Learning, Teaching and Educational Research, 17*(5), 64–81. https://doi.org/10.26803/ijilter.17.5.5

Gottwald, S., Morris, R., Wolf, M., & Galyean, T. (2017). Bringing the Bottom Billion into Basic Literacy: How We Can and Why We Must. *New Directions for Child and Adolescent Development, 158*, 93–104. https://doi.org/10.1002/cad.20225

Gulati, S. (2008). Technology-enhanced learning in developing nations: A review. *International Review of Research in Open and Distance Learning, 9*(1), 1–16. https://doi.org/10.19173/irrodl.v9i1.477

Haßler, B., Major, L., & Hennessy, S. (2016). Tablet use in schools: A critical review of the evidence for learning outcomes. *Journal of Computer Assisted Learning, 32*(2), 139–156. https://doi.org/10.1111/jcal.12123

Hirsh-Pasek, K., Zosh, J. M., Golinkoff, R. M., Gray, J. H., Robb, M. B., & Kaufman, J. (2015). Putting education in "educational" apps: Lessons from the science of learning. *Psychological Science in the Public Interest, 16*(1), 3–34. https://doi.org/10.1177/1529100615569721

Howitt, D. (2016). *Introduction to Qualitative Research Methods in Psychology* (3rd Ed.). Pearson.

Hsin, C. T., Li, M. C., & Tsai, C. C. (2014). The influence of young children's use of technology on their learning: A review. *Journal of Educational Technology & Society, 17*(4), 85–99.

Huntington, B., Goulding, J., & Pitchford, N. J. (2023). Pedagogical features of interactive apps for effective learning of foundational skills. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.13317

Islam, M. S., & Grönlund. (2016). An international literature review of 1:1 computing in schools. *Journal of Educational Change, 17*(2), 191–222. https://doi.org/10.1007/s10833-016-9271-y

Ito, H., Kasai, K., & Nakamuro, M. (2019). Does Computer-Aided Instruction Improve Children's Cognitive and Non-Cognitive Skills? Evidence from Cambodia. *Discussion Papers 19040*. Research Institute of Economy, Trade and Industry (RIETI. https://ideas.repec.org/p/eti/dpaper/19040.html.

Jones, A., Scanlon, E., Gaved, M., Blake, C., Collins, T., Clough, G., & Twiner, A. (2013). Challenges in personalisation: supporting mobile science inquiry learning across contexts. *Research and Practice in Technology Enhanced Learning, 8*(1), 21–42.

Jordan, K., Proctor, J., Koomar, S., & Bapna, A. (2021). *A Country-Level Research Review: EdTech in Tanzania*. EdTech Hub. https://docs.edtechhub.org/lib/RQGJRKVS/download/UQYUKTMB/Jordan%20et%20al_2021_A%20Country-Level%20Research%20Review.pdf.

Kaguo, F. E. (2011). Factors influencing academic performance of students in community and government built secondary schools in Mbeya municipality, Tanzania [. *Doctoral dissertation*. Sokoine University of Agriculture.].

Kallio, H., Pietilä, A. M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing, 72*(12), 2954–2965. https://doi.org/10.1111/jan.13031

Keengwe, J., & Bhargava, M. (2013). Mobile learning and integration of mobile technologies in education. *Education and Information Technologies, 19*(4), 737–746. https://doi.org/10.1007/s10639-013-9250-3

King, S., Pressley, J., & Gove, A. (2019). *Global Learning XPRIZE – Impact Data Summary*. https://shared.rti.org/content/global-learning-xprize-data-summary.

Kolak, J., Norgate, S. H., Monaghan, P., & Taylor, G. (2021). Developing evaluation tools for assessing the educational potential of apps for preschool children in the UK. *Journal of Children and Media, 15*(3), 410–430. https://doi.org/10.1080/17482798.2020.1844776

Lai, F., Zhang, L., Hu, X., Qu, Q., Shi, Y., Qiao, Y., Boswell, M., & Rozelle, S. (2013). Computer assisted learning as extracurricular tutor? Evidence from a randomised experiment in rural boarding schools in Shaanxi. *Journal of Development Effectiveness, 5*(2), 208–231. https://doi.org/10.1080/19439342.2013.780089

Lan, Y. J. (2018). Technology enhanced learner ownership and learner autonomy through creation. *Educational Technology Research and Development, 66*(4), 859–862. https://doi.org/10.1007/s11423-018-9608-8

Levitt, H. M. (2018). How to conduct a qualitative meta-analysis: Tailoring methods to enhance methodological integrity. *Psychotherapy Research, 28*(3), 367–378. https://doi.org/10.1080/10503307.2018.1447708

Lewis, I. M. (2021). Witchcraft - Witchcraft in Africa and the world. *Encyclopaedia Britannica*. https://www.britannica.com/topic/witchcraft/Witchcraft-in-Africa-and-the-world.

Lurvink, A. F., & Pitchford, N. J. (2023). Introduction of an EdTech intervention to support learning of foundational skills in Sierra Leone: policy, teacher, and community perspectives. *Frontiers in Education, 8*. https://doi.org/10.3389/feduc.2023.1069857

Maguire, M., & Delahunt, B. (2017). Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *All Ireland Journal of Higher Education, 9*(3), 3351–3354.

Major, L., Francis, G. A., & Tsapali, M. (2021). The effectiveness of technology-supported personalised learning in low-and middle-income countries: A meta-analysis. *British Journal of Educational Technology*, (5), 52. https://doi.org/10.1111/bjet.13116

Major, L., & Francis, G. (2020). *Technology-supported personalised learning: Rapid evidence review*. EdTech Hub. https://edtechhub.org/wp-content/uploads/2020/09/Rapid-Evidence-Review_-Technology-supported-personalised-learning.pdf.

McCormack, B., Rycroft-Malone, J., DeCorby, K., Hutchinson, A. M., Bucknall, T., Kent, B., & Wilson, V. (2013). A realist review of interventions and strategies to promote evidence-informed healthcare: a focus on change agency. *Implementation Science, 8*(1), 1–12. https://doi.org/10.1186/1748-5908-8-107

Moss, C. (2020). *18 large-scale EdTech initiatives on our radar in 2020*. Jan 22. EdTech Hub https://edtechhub.org/2020/01/22/18-large-scale-edtech-initiatives-on-our-radar-in-2020/.

Mouza, C., & Cavalier, A. (2013). The Role of One-to-One Computing in the Education of at-Risk High-School Students. *Emerging Technologies for the Classroom*, 145–159. https://doi.org/10.1007/978-1-4614-4696-5_10

Muhammad, N. M., Schneider, M., Hill, A., & Yau, D. M. (2019). The Negative Impacts of EdTech: EQ Perspectives. In *Society for Information Technology & Teacher Education International Conference* (pp. 1066–1071). Association for the Advancement of Computing in Education (AACE).

Outhwaite, L. A., Early, E., Herodotou, C., & Van Herwegen, J. (2023). Understanding how educational maths apps can enhance learning: A content analysis and qualitative comparative analysis. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.13339

Outhwaite, L. A., Faulder, M., Gulliford, A., & Pitchford, N. J. (2019). Raising early achievement in math with interactive apps: A randomized control trial. *Journal of Educational Psychology, 111*(2), 284. https://doi.org/10.1037/edu0000286

Outhwaite, L. A., Gulliford, A., & Pitchford, N. J. (2020). Language counts when learning mathematics with interactive apps. *British Journal of Educational Technology, 51*(6), 2326–2339. https://doi.org/10.1111/bjet.12912

Paradowski, M. B. (2015). Holes in SOLEs: re-examining the role of EdTech and 'minimally invasive education' in foreign language learning and teaching. *English Lingua Journal, 1*(1), 37–60.

Passey, D., Laferrière, T., Ahmad, Y.-A., Bhowmik, M., Gross, D., Price, J., & Shonfeld, M. (2016). Educational Digital Technologies in Developing Countries Challenge Third Party Providers. *Journal of Educational Technology & Society, 19*(3), 121–133.

Pegrum, M., Howitt, C., & Striepe, M. (2013). Learning to take the tablet: How pre-service teachers use iPads to facilitate their learning. *Australasian Journal of Educational Technology, 29*(4). https://doi.org/10.14742/ajet.187

Pitchford, N. J., & Outhwaite, L. A. (2016). The use of tablet technology to support development of early mathematical skills: A cross cultural comparison. In N. Kucirkova, & G. Falloon (Eds.), *Apps, Technology and Younger Learners: International Evidence for Teaching* (pp. 121–134).

Pitchford, N. J., Kamchedzera, E., Hubber, P. J., & Chigeda, A. L. (2018). Interactive apps promote learning of basic mathematics in children with special educational needs and disabilities. *Frontiers in Psychology, 9*(262). https://doi.org/10.3389/fpsyg.2018.00262

Power, T., Buckler, A., Ebubedike, M., Tengenesha, M., Jama, M., Ndlovu, A., & Mubaira, S. (2021). *Community Help for Inclusive Learning and Development (CHILD): A Study of How Mobile Phones Were Used to Recruit and Equip Community Volunteers to*

Support Children's Learning During Covid-19 School Closures in Zimbabwe. EdTech Hub. https://docs.edtechhub.org/lib/HZRHPNI5/download/VU88LKN8/Community%20Help%20for%20Inclusive%20Learning%20and%20Development_Final.pdf.

Robson, C. (2002). *Real World Research* (2nd Ed.). Blackwell: Oxford.

Rodriguez-Segura, D. (2020). *Educational technology in developing countries: A systematic review*. University of Virginia EdPolicy Works Working Papers.

Shukia, R., Katabaro, J., & Mgumia, J. (2019). *Social Emotional Impact Assessment Draft Report. Report prepared for UNESCO,* Tanzania. [Unpublished manuscript].

Spieth, P. M., Kubasch, A. S., Penzlin, A. I., Illigens, B. M. W., Barlinn, K., & Siepmann, T. (2016). Randomized controlled trials–a matter of design. *Neuropsychiatric Disease and Treatment, 12*, 1341–1349. https://doi.org/10.2147/NDT.S101938

Statista (2021, Apr 7). *Global digital population as of January 2021*. https://www.statista.com/statistics/617136/digital-population-worldwide/.

Stubbé, H., Badri, A., Telford, R., van der Hulst, A., & van Joolingen, W. (2016). E-Learning Sudan, Formal Learning for Out-of-School Children. *Electronic Journal of e-Learning, 14*(2), 136–149.

Suminar, D. R., & Wardana, N. D. (2018). Thematic Analysis of The Symbolic And Imaginary Play Indonesian Children. *The International Journal of Social Sciences and Humanities Invention, 5*(11), 5066–5071. https://doi.org/10.18535/IJSSHI/V5I11.01

Tamim, R. M., Borokhovski, E., Pickup, D., Bernard, R. M., & El Saadi, L. (2015). *Tablets for Teaching and Learning: A Systematic Review and Meta-Analysis.* http://oasis.col.org/bitstream/handle/11599/1012/2015_Tamim-et-al_Tablets-for-Teaching-andLearning.pdf.

Tauson, M. & Stannard, L. (2018). *EdTech for learning in emergencies and displaced settings*. London: Save the Children. https://resourcecentre.savethechildren.net/sites/default/files/documents/edtech-learning.pdf.

The Economist. (2018, February 22). *A fuss over Freemasons in Africa.* https://www.economist.com/middle-east-and-africa/2018/02/22/a-fuss-over-freemasons-in-africa.

The World Bank. (2021, April 18). *Keeping Bangladesh's Students Learning during the COVID-19 Pandemic – Results Brief.* https://www.worldbank.org/en/results/2021/04/18/keeping-bangladesh-s-students-learning-during-the-covid-19-pandemic.

The World Bank (2019, January 22). *Pass or fail? How can the world do its homework*. https://www.worldbank.org/en/news/immersive-story/2019/01/22/pass-or-fail-how-can-the-world-do-its-homework.

The World Bank. (2018). *World Development Report 2018: Learning to Realize Education's Promise*. Washington, DC: World Bank.

Trainor, L. R., & Bundon, A. (2020). Developing the craft: reflexive accounts of doing reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health, 13*, 1–22. https://doi.org/10.1080/2159676X.2020.1840423

UNESCO. (2021). *100 million more children under children under minimum reading proficiency level due to COVID-19- UNESCO convenes world ministers.* https://www.unesco.org/en/articles/100-million-more-children-under-minimum-reading-proficiency-level-due-covid-19-unesco-convenes-world.

UNESCO. (2019). *GEM Report: Migration, displacement and education- Building bridges, not walls.* https://gem-report-2019.unesco.org/.

UNESCO. (2022, September). *New estimation confirms out-of-school population is growing in Sub-Saharan Africa – Policy Paper.* https://www.unesco.org/gem-report/en/2022-out-school#:~:text=It%20is%20estimated%20that%20244,and%20125.5%20million%20were%20boys.

UNICEF. (2022a). *70 percent of 10-year-olds in 'learning poverty' unable to read and understand a simple text.* https://www.unicef.org/press-releases/70-cent-10-year-olds-learning-poverty-unable-read-and-understand-simple-text.

UNICEF. (2022b). *The State of Global Learning Poverty*. https://thedocs.worldbank.org/en/doc/e52f55322528903b27f1b7e61238e416-0200022022/original/Learning-poverty-report-2022-06-21-final-V7-0-conferenceEdition.pdf.

United Nations Development Programme (UNDP). (2023). *Goal 4: Quality Education.* https://www.undp.org/sustainable-development-goals/quality-education.

Verdolini, E., Anadón, L. D., Baker, E., Bosetti, V., & Aleluia Reis, L. (2018). Future prospects for energy technologies: Insights from expert elicitations. *Review of Environmental Economics and Policy, 12*(1), 133–153. https://doi.org/10.1093/reep/rex028

Walton, J. M. (2018). *Evaluating the impact of a tablet-based intervention on the mathematics attainment, receptive language and approaches to learning of preschool children* (Doctoral dissertation). University of Nottingham.

Wang, G., Zhang, Y., Zhao, J., Zhang, J., & Jiang, F. (2020). Mitigate the effects of home confinement on children during the COVID-19 outbreak. *The Lancet, 395*(10228), 945–947. https://doi.org/10.1016/S0140-6736(20)30547-X

XPRIZE. (2019). *Global Learning XPRIZE Executive Summary*. https://www.xprize.org/prizes/global-learning/articles/glexp-executive-summary.