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Mobile-assisted indigenous language learning: RCT evidence from a school-based intervention in Peru

Emma Näslund-Hadley^a, Juan Manuel Hernández-Agramonte^b, Humberto Santos^c, and Hugo Us^d

^aEducation Division, Inter-American Development Bank (IDB), Washington, USA; ^bInnovations for Poverty Action (IPA), Washington, USA; ^cIndependent Researcher, Imola (BO), Italy; ^dGender and Diversity Division, Inter-American Development Bank (IDB), Ciudad de Guatemala, Guatemala

ABSTRACT


This study presents the results of an experimental evaluation of a pedagogical intervention based on the mobile application Quechua Collao, designed to strengthen Quechua skills as a second language among primary and secondary school students in schools with an Intercultural Bilingual Education (IBE) approach in Peru. The intervention combined the use of the app with a structured pedagogical guide and specialized teacher support. Results show positive effects on reading, listening, and speaking skills, with an overall impact of 0.137 standard deviations (SD) on a general assessment, and larger effects (0.330 SD) on a test aligned with the app's content. In addition, increases were observed in the use of Quechua in public spaces (0.187 SD) and in interactions outside the family setting (0.176 SD). These effects were more pronounced among students with lower initial levels of Quechua proficiency and use, suggesting a contribution to processes of language revitalization. While no significant changes were detected in perceptions of Quechua or in experiences of discrimination, the increased use of the language reflects a shift in social practices. Taken together, the findings are promising: they offer a concrete pathway to address several barriers that hinder the effective implementation of IBE in Latin American classrooms.

Introduction

Despite progress in expanding access to primary and secondary education for Indigenous children in Latin America and the Caribbean (LAC), recent studies show persistent gaps in enrollment, retention, and learning outcomes (e.g., Corbetta, 2021; Näslund-Hadley & Santos, 2022; Organización de Estados Iberoamericanos [OEI], 2015; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2021a, 2021b). To address these inequities, governments have pursued broader education reforms (Näslund-Hadley & Santos, 2022) – such as equitable resource allocation, teacher training, and targeted investment in disadvantaged schools – while also adopting IBE models that are specifically aimed at improving Indigenous students' learning outcomes and promoting the revitalization and preservation of Indigenous cultures and languages, many of which face erosion or extinction (Porter & Morrison, 2024).

However, recent evidence highlights persistent challenges in the classroom implementation of IBE in LAC (Santos et al., 2025). These challenges include the limited use of Indigenous languages as the

CONTACT Emma Näslund-Hadley  emman@iadb.org  Education Division, Inter-American Development Bank (IDB), 1300 New York Avenue NW, Washington DC 20577, USA

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medium of instruction, the insufficient integration of students' cultural knowledge into teaching practices, and the lack of pedagogical approaches suited to culturally and linguistically diverse contexts. The literature attributes these shortcomings to several interrelated factors, including shortages of bilingual and culturally relevant learning materials, limited teacher preparation in Indigenous languages and cultures, weaknesses in initial teacher education and in-service training, and low levels of school–community engagement (e.g., Corbetta, 2021; Drouet et al., 2025; García & Velasco, 2012; López, 2009; Manresa-Axisa, 2018; Rodríguez Cruz, 2018; Schmelkes & Ballesteros, 2020; UNESCO, 2021c; Valdiviezo, 2009, 2010).

Recent advances in digital technologies and the widespread penetration of mobile devices, particularly smartphones (see Figures 1 and 2), have fueled a growing interest in their use for language learning, including Indigenous languages (Galla, 2016; United Nations Educational, Scientific and Cultural Organization, 2025). Mobile-assisted interventions offer several advantages. First, unlike language classes or conventional study materials, mobile applications (apps) provide a form of economic accessibility because learners often already possess the device used for learning (Cassels & Farr, 2019), which is particularly relevant for IBE in LAC, where there is both a shortage of teachers with knowledge of Indigenous languages and cultures and a lack of contextually adapted learning materials (Bocarejo et al., 2022; Yahuarcani et al., 2021). Second, mobile technologies enable learning anytime and anywhere (Chen et al., 2020; Cho et al., 2018; Criollo-C et al., 2021; Lin & Lin, 2019), a key feature for Indigenous languages given the geographic isolation of many communities and the limited exposure to native speakers among migrants in urban areas (Galla, 2016; López, 2020). Moreover, because these languages are rarely studied for academic or professional purposes, the time available for learning tends to be limited (Cassels & Farr, 2019). Third, mobile tools allow for personalized content tailored to students' interests, needs, and abilities (Cho et al., 2018; Lin & Lin, 2019; Muckenhuber et al., 2023) and can contextualize learning by integrating knowledge and experiences acquired outside the classroom (Chen et al., 2020; Mahdi, 2017). Fourth, the technical affordances of mobile devices (e.g., voice recording and playback, cameras, web navigation) facilitate collaborative and social activities, interactive real-time experiences, and gamification-based approaches (Cho et al., 2018; Crow, 2015; Lin & Lin, 2019), which are especially appealing to younger learners (Galla, 2016). Finally, the private feedback that these platforms provide can help reduce anxiety about making grammatical or pronunciation mistakes, as well as mitigate the prejudice and discrimination that often surround Indigenous language learning (Cassels & Farr, 2019).

Despite these opportunities, the literature also highlights several challenges linked to the use of mobile devices for language learning. For instance, some studies note that users often perceive these devices primarily as tools for personal and social interaction rather than educational purposes, due to distractions, physical limitations (e.g., small screen and keyboard size), and concerns over data privacy (Lin & Lin, 2019). Cost is another barrier, as mobile devices, networks, and internet connectivity remain less accessible in rural or low-income areas – conditions common in many Indigenous communities (Galla, 2016; Näslund-Hadley & Santos, 2022). In addition, many Indigenous communities express skepticism about the capacity of digital tools to transmit core cultural knowledge and raise concerns about ownership and intellectual property rights (Cassels & Farr, 2019). Some also view the growing use of technology as contributing to the weakening of intergenerational Indigenous language transmission among younger generations (Galla, 2016). Finally, the wide diversity of linguistic variants within a single Indigenous language presents further challenges for the development and scaling of digital learning tools (Cassels & Farr, 2019; Santos et al., 2025).

Despite the growing proliferation of mobile-assisted language learning (MALL) methodologies, rigorous evidence on their effectiveness remains limited. Nonetheless, systematic reviews and meta-analyses of experimental and quasi-experimental studies provide a preliminary assessment of their impact on first (L1) and second language (L2) learning. These studies consistently find that interventions using mobile devices (Burston, 2015; Chen et al., 2020; Cho et al., 2018; Hassan Taj et al., 2016; Lin & Lin, 2019; Mahdi, 2017; Sung et al., 2015) and, more specifically, apps designed for smartphones and tablets (Mihaylova et al., 2022), generate positive effects across a wide range of linguistic skills – including

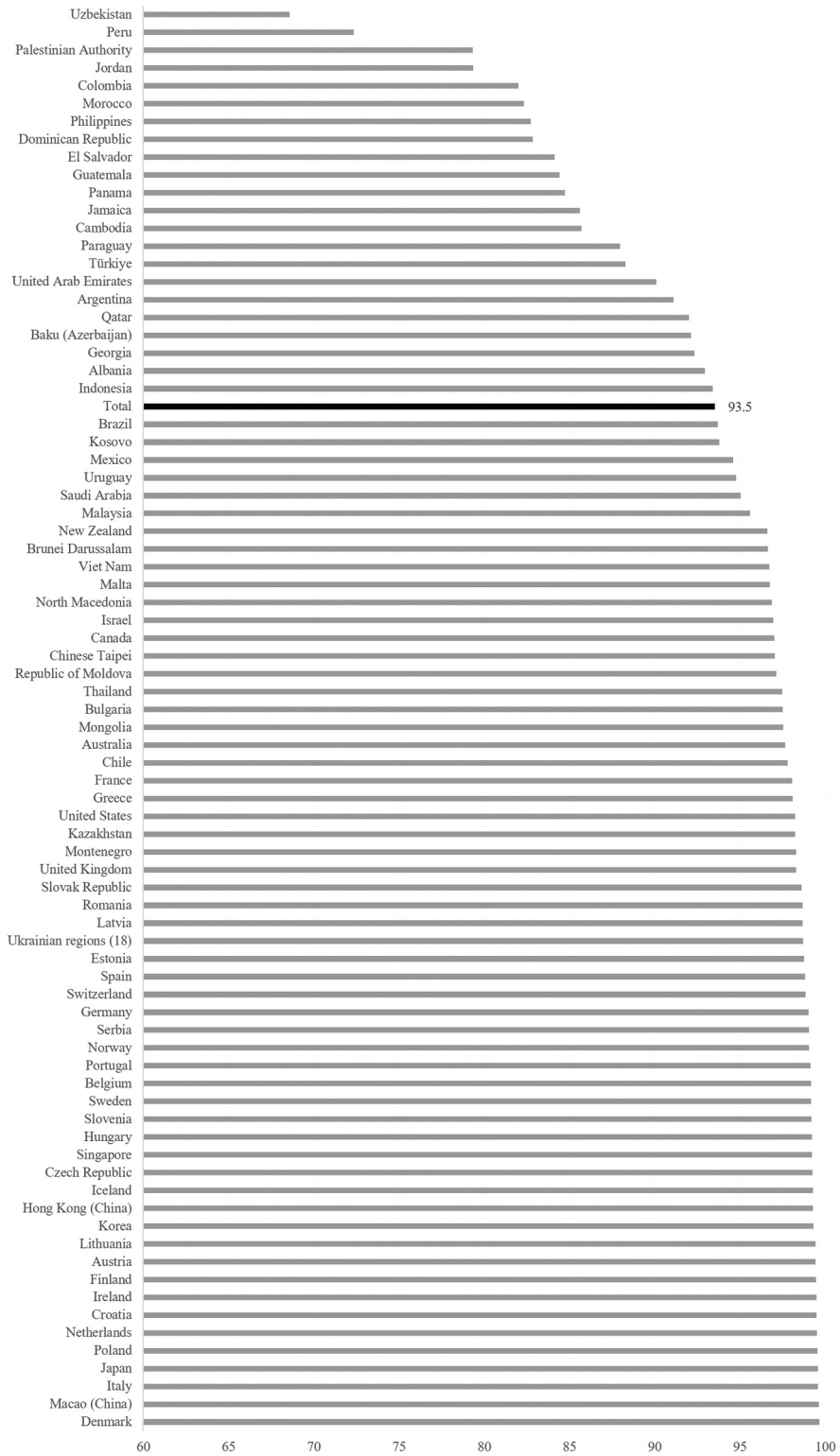


Figure 1. Percentage of 15-year-old students who own a mobile phone with internet access (%). Authors' own elaboration based on the PISA 2022 student questionnaire. Total corresponds to the percentage calculated for the full sample.



Figure 2. Percentage of 15-year-old students who use an internet-connected mobile phone outside school every day or almost every day, or several times a day (%). Authors' own elaboration based on the PISA 2022 student questionnaire. Total corresponds to the percentage calculated for the full sample.

speaking, listening, reading, writing, vocabulary acquisition, pronunciation, grammar, spelling, and early literacy – compared to traditional approaches based on printed materials or desktop computers. Reported average effect sizes range from moderate to large, between 0.5 and 1 standard deviation.

However, this body of literature also reveals important limitations that underscore a significant evidence gap. First, only a small number of studies employ rigorous designs, including pre- and post-treatment measures, randomized treatment and control groups, and sufficiently large samples. Second, most existing evidence is concentrated on English as a foreign language and university populations, with little attention to other languages or younger learners. For example, in the case of Indigenous languages, although numerous apps have been developed to support their instruction¹ (Koole et al., 2023), no causal evaluations of their impact on learning have been conducted (Cassels & Farr, 2019; Montes Santiago et al., 2023).

To address these gaps in the literature on the effectiveness of MALL, this article presents the first randomized controlled trial (RCT) evaluating a school-based mobile intervention for the learning of an Indigenous language in LAC. The study assesses Quechua Collao, a pedagogical intervention designed to strengthen Quechua as a second language (L2) among primary and secondary students in public IBE schools in Peru. Quechua Collao is a variant of Quechua spoken mainly in southern Peru, particularly in the departments of Apurímac, Cusco, Puno, Arequipa, and Moquegua (Ministerio de Cultura del Perú, n.d.). The intervention combined an app featuring culturally relevant, gamified activities targeting listening, reading, and writing skills with structured pedagogical guides and specialized teacher support integrated into regular classroom instruction. The evaluation was conducted between August and December 2024 with 4,464 students across 200 IBE schools in the departments of Cusco and Puno.

Based on the intervention and evaluation described above, the article addresses the following research questions. First, was the Quechua Collao intervention effective in improving students' Quechua language skills – specifically listening, reading, and speaking? Second, did the intervention have an impact on other relevant dimensions of language learning, such as students' perceptions of Quechua, their frequency of language use, and their experiences of discrimination related to their origin, culture, or mother tongue? Third, do the effects of the intervention vary depending on students' initial levels of Quechua proficiency?

Context of the intervention

IBE in Peru

In Peru, IBE has been institutionalized as a policy aimed at incorporating the country's 48 Indigenous languages (including Quechua and its variants), alongside Spanish, as languages of instruction. Implementation is led by the Ministry of Education (MINEDU), the governing body of the education system, together with regional governments through the Regional Education Directorates (*Dirección Regional de Educación* or DRE) and the Local Educational Management Units (*Unidad de Gestión Educativa Local* or UGEL). The DREs and UGELs are responsible, among other functions, for identifying schools that serve Indigenous students, recruiting and supporting teachers, and distributing and monitoring the use of educational materials in IBE schools (United Nations Children's Fund [UNICEF], n.d.). According to the National Registry of Educational Institutions offering IBE (*Registro Nacional de Instituciones Educativas que brindan el servicio de EIB* or RNIIEE EIB), there are currently 26,422 IBE schools, serving 1,203,697 children and adolescents and employing 103,853 teachers.

Under the IBE Service Model (*Modelo de Servicio Educativo Intercultural Bilingüe* or MSEIB), recently updated by the MINEDU, two modalities of school-based educational provision are distinguished according to the vitality of Indigenous languages in each community: (1) language strengthening, aimed at students whose mother tongue is an Indigenous language, and (2) language revitalization, targeting students who, although belonging to Indigenous peoples, no longer actively speak the language. In strengthening contexts, the

model aims to build upon students' learning using the Indigenous language as their first language. In revitalization contexts, by contrast, the goal is to reintroduce the language as a heritage language and promote its re-learning in institutional settings that recognize its symbolic and cultural value (Ministerio de Educación del Perú [MINEDU], 2024). This approach is based on the principle that learning the Indigenous language is not only an educational process but also a form of cultural identity affirmation (MINEDU, 2013).

However, the implementation of IBE in Peru has faced persistent structural challenges, including the limited availability of bilingual teachers with training in IBE, the lack of structured teaching materials in Indigenous languages for all educational levels and across the wide diversity of languages, as well as significant inequalities in educational infrastructure, particularly in rural areas (Barragán Lara et al., 2024; Hidalgo Collazos & Ordóñez Hidalgo, 2025). Although this diagnosis refers to the Peruvian IBE system in general, there is evidence that these challenges are also present in the specific case of Quechua-language education (Valdiviezo, 2009, 2010). Some of these gaps are further exacerbated in contexts of language revitalization, such as in urban areas, where students no longer speak an Indigenous language as their mother tongue.

Use of the Quechua language

According to the National Institute of Statistics and Informatics of Peru (INEI), nearly 4 million people speak it as their mother tongue, representing approximately 16% of the national population. Although Quechua has been officially recognized by the Peruvian state, its effective presence in public and educational spaces remains limited. For example, Julca Guerrero (2000), through an analysis of sociolinguistic patterns, documents that Quechua is predominantly used in family and intimate contexts, especially with older individuals or members of the immediate community. In contrast, Spanish prevails in public, institutional, and educational domains.

These social practices are reflected in implicit perceptions toward Quechua and its speakers. For instance, Marcinko (2023), using the experimental Matched-Guise technique, shows that Quechua is associated with positive attributes such as kindness and social closeness, but also, implicitly, with lower socioeconomic status and weaker academic competence compared to Spanish. These perceptions, internalized by both speakers and non-speakers, directly influence the value ascribed to the language, shaping its learning and effective use in formal contexts.

Similarly, Kvietok Dueñas's (2021) ethnographic study reveals that bilingual youth face significant social pressures regarding the use of Spanish and Quechua: from feelings of shame or discrimination associated with limited command of Spanish, to frustration at being excluded within their own families or communities for not mastering Quechua. Nevertheless, the study also highlights a genuine interest among many young people in learning Quechua, particularly when provided with meaningful spaces and pedagogical methods that align with their communicative expectations. Interviewed students expressed a desire for more participatory approaches, the use of audiovisual materials, opportunities for authentic interactions in Quechua, and teachers with flexible methodologies that acknowledge and value their diverse linguistic trajectories. This interest stands in contrast to the limitations of resources, time, and pedagogical quality observed in the traditional teaching of Quechua in secondary schools.

Intervention description

The Quechua Collao intervention consists of an integrated package comprising an app, printed pedagogical guides, and teacher support. This section describes each component and how they interact to implement the program's curricular plan.

Curricular plan

Pedagogical purpose and general approach

The pedagogical approach of the intervention is grounded in the principles of the communicative and functional approach to second-language instruction, adapted to IBE and to language-revitalization contexts in which Quechua is learned as a second or heritage language. This approach focuses on developing students' communicative competence, defined as the ability to communicate effectively and appropriately across diverse contexts. Such competence involves not only knowledge of grammatical rules but also the social and cognitive skills required for the functional use of language (Lillis, 2006). Beyond grammar, the approach incorporates sociolinguistic, discourse, and strategic dimensions of language (Canale & Swain, 1980). As a result, it emphasizes the meaningful use of the target language, by encouraging interaction, the resolution of communicative tasks, and the functional appropriation of language in authentic contexts. These characteristics are considered fundamental principles for the development of second-language competence (Ellis, 2005).

The activities are structured around three complementary components. First, the Quechua Collao app, designed to operate offline, included listening, repetition, voice recording, and game-based activities, along with immediate feedback and visual scaffolding, all of which supported oral interaction and familiarization with basic Quechua structures. Its design draws on the literature on MALL effectiveness, which suggests that personalization, contextualization, motivational features – such as gamified activities – and individualized feedback are associated with improved language learning outcomes (Cassels & Farr, 2019; Chen et al., 2020; Cho et al., 2018; Ishaq et al., 2021; Lin & Lin, 2019). Second, each lesson of the app was accompanied by printed pedagogical guides, distributed to all participating teachers, which provided oral, written, and linguistic reflection activities that reinforced the app's content while also supporting integration with regular classroom dynamics. Finally, the intervention incorporated in-person oral activities – such as dramatizations, role plays, participatory dynamics, and language games – designed to consolidate vocabulary, grammatical structures, and fluency in oral production.

The intervention also recognizes the diverse linguistic backgrounds of students in each region and promotes respect for Quechua as an essential component of local cultural heritage, integrating into its methodology communicative situations drawn from school and family contexts.

Curriculum design and pedagogical resources

The curricular design of the intervention was structured around three thematic units that reflected key aspects of students' everyday lives: school, recess, and home. Each unit included three to four pedagogical guides, which could be implemented in one or more sessions depending on the class time available in each school and section (i.e., a class group within the same grade). These guides were aligned with the principles of the National Curriculum Design for IBE contexts where an Indigenous language is taught as a second language (L2) (MINEDU, 2019), and they integrated core competencies in listening comprehension, speaking, reading, and writing.

Each guide was organized around a communicative situation drawn from students' daily experiences, through which thematic vocabulary was introduced (e.g., people at school, household objects, or common actions). The activities followed a structured sequence consisting of three phases: an introductory phase designed to motivate and activate prior knowledge; a development phase focused on app use and oral practice; and a closing phase that encouraged reflection, written production, or reinforcement through review games. This sequencing aligns with task-based language teaching frameworks, which distinguish between pre-task activation, task performance, and post-task reflection and language focus (Willis & Willis, 2007).

Key grammatical structures were progressively incorporated, such as the use of personal pronouns, verb forms in the simple present and present progressive, and interrogative, locative, and direct object suffixes. Throughout the units, there is a clear progression in the grammatical and communicative complexity of the structures introduced. For example, the initial guides present the use of verbs in the

Table 1. Curriculum guide for learning Quechua Collao.

Thematic unit	Guide	Brief description	Linguistic components covered
Unit 1: School	1	Introduces basic expressions to identify members of the school community and describe their actions.	Verbs <i>rimay</i> (to speak), <i>qillqay</i> (to write), <i>ñawinchay</i> (to read); simple present; affirmative structures.
	2	Teaches how to ask closed questions with “-chu” about school-related actions.	Present progressive; negations; listening comprehension.
	3	Introduces the use of personal pronouns in subject + verb + object sentences.	<i>ñuqa</i> (I), <i>qam</i> (you), <i>pay</i> (he/she); personal conjugations.
Unit 2: Recess	4	Vocabulary related to food and daily actions during recess.	Verbs <i>mikhuy</i> (to eat), <i>upyay</i> (to drink); suffix “-ta.”
	5	Describes actions according to location in the school.	Questions with <i>maypim</i> (where?); locative suffix “-pi.”
	6	Practices greetings, farewells, and spatial references for actions.	<i>allin p'unchaw</i> (good morning), <i>tupananchikkama</i> (see you soon); spatial connectors.
Unit 3: Home	7	Describes hobbies at home using pronouns and objects.	<i>ñuqa</i> (I), <i>qam</i> (you); suffixes “-ni,” “-nki,” and “-n.”
	8	Reports family activities in the first and third person.	Verbs <i>qhawariy</i> (to watch), <i>ñawinchay</i> (to read), <i>upyay</i> (to drink); suffixes “-ni,” “-n,” and “-nchik.”
	9	Introduces plural forms through collective actions.	<i>qamkuna</i> (you all), <i>paykuna</i> (they); suffixes “-nkichik” and “-nku.”

third person singular alongside basic pronouns such as *ñuqa* (I), *qam* (you), and *pay* (he/she). In the later units, plural pronouns such as *qamkuna* (you [plural]) and *paykuna* (they) are incorporated, together with verb conjugations in the first-, second-, and third-person plural. This sequencing is consistent with research in second language acquisition, which suggests that grammatical structures are acquired in developmental sequences, supporting the progressive introduction of increasing grammatical and communicative complexity (Pienemann, 1998).

The Quechua Collao app serves as the organizing axis of each session. Its contents are organized into units and lessons, allowing students to develop listening skills while engaging in activities such as repetition, voice recording, visual association, and multiple-choice tasks. The app is designed to support both autonomous student use and guided implementation by teachers or pedagogical trainers. Table 1 presents the thematic units, the corresponding pedagogical guides, and the linguistic components addressed in each.

The main menu of the app is structured around thematic units (Figure 3). Each unit includes three topics, with four to five lessons per topic, and a progress bar displays the learner’s advancement within the selected topic (Figure 4). Lessons begin with simple linguistic elements – such as pronouns, nouns, and verbs – that can be played in audio format and practiced through recognition tasks in both oral and written form. As learners progress, the content becomes increasingly complex, incorporating verb conjugation and the combination of pronouns, nouns, and interrogative sentences. Figure 5 illustrates examples from Topic 1 of Unit 1: an initial task presenting a Quechua sentence with its Spanish translation and corresponding audio (panel a); an exercise where students match a Spanish sentence with the correct Quechua audio option (panel b); another requiring them to select the appropriate Quechua translation of a Spanish sentence (panel c); and a final task in which words must be arranged in the correct order to form coherent sentences (panel d).

The Organization of Ibero-American States (OEI) installed the app directly on students’ tablets, since it is not available on open platforms such as the Play Store. The app is designed exclusively for devices with the Android operating system and can be used without an internet connection.

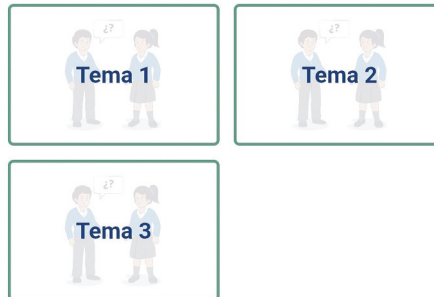
Classroom implementation

The planned classroom implementation involved interaction between the teacher and a pedagogical trainer. Teachers were expected to be responsible for implementing the intervention during the two instructional hours allocated to the course Communication in a Second Language for sixth-grade

Quechua



Unidad 1: La Escuela



Unidad 2: El Recreo

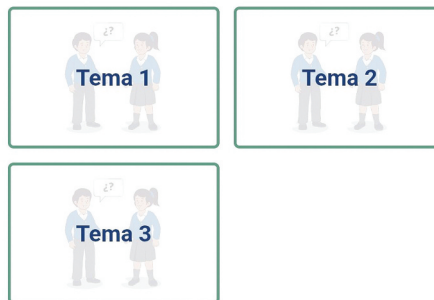


Figure 3. Main menu of the Quechua Collao app.

primary (aged 11–12 years) and first-year secondary students (aged 12–14 years), with pedagogical trainers providing guidance and support. The pedagogical trainers were professionals recruited and trained by the OEI, with backgrounds in IBE or experience in teaching Quechua as a second language. Their responsibilities included coordinating with school principals to install the app on tablets, ensuring that devices were ready for pedagogical use. They also trained teachers, providing detailed guidance on the structure of the sessions and on the use of the app. Subsequently, they supported classroom implementation through weekly visits, aimed at ensuring the proper execution of the intervention and addressing emerging questions. The team consisted of 19 trainers, each of whom worked with between 4 and 6 schools.

However, two practical challenges led to adjustments in the implementation of the intervention. First, due to coordination constraints related to school schedules, teachers from other subject areas – such as science or mathematics, rather than the official Quechua teachers – allocated part of their instructional time to ensure the continuity of the planned sessions. Second, during the preparation phase, the OEI identified heterogeneity in teachers' oral and written proficiency in Quechua, which limited the feasibility of establishing a uniform, teacher-led implementation standard.

In response to these challenges, and with the aim of ensuring pedagogical consistency and quality, the intervention was implemented through three possible modalities: direct, mixed, and indirect. In the direct modality, pedagogical trainers led most of the classroom sessions. In the mixed modality,



Figure 4. Lessons by topic.



Figure 5. Activities of Topic 1 of Unit 1.

trainers and teachers jointly conducted the sessions; this modality was implemented in cases where teachers had sufficient proficiency in Quechua and their schedules aligned with planned visits. Finally, under the indirect modality, teachers led the sessions with remote monitoring and support from the pedagogical trainer.

The intervention was implemented between August 5 and November 15, 2024, in schools in the departments of Cusco and Puno, covering a total of 242 treated sections (class group) and 2,401

Table 2. Weekly time allocation and final guide completed (average).

Weekly time allocation	Final guide completed (average)	Sections	
		N	%
Up to 30 min	5	7	2.9
Up to 60 min	9	80	33.1
Up to 90 min	9	151	62.4
Up to 120 min	9	4	1.7
Total		242	100.0

Source: OEI monitoring data.

participating students, in coordination with the corresponding UGELs. Of these sections, 220 (91%) followed the direct modality, 10 (4%) the mixed modality, and 12 (5%) the indirect modality. By educational level, 119 sections corresponded to sixth grade of primary school (49%) and 123 to first grade of secondary school (51%). Although most sessions were conducted directly by the pedagogical trainers, the teachers designated by each school to accompany the intervention played a key logistical role. They ensured that devices were charged and ready for use, were familiar with the structure of the sessions, and, in most cases, remained in the classroom during implementation. Teachers who regularly accompanied the process received a certificate in recognition of their participation and support in the project's implementation.

In addition to the mode of delivery, one of the main sources of heterogeneity in implementation was the weekly time allocation that each school assigned to Indigenous language sessions. These decisions – primarily made by school principals in coordination with teachers – determined whether the sessions were conducted in blocks of 30, 60, 90, or even 120 minutes per week. This variability in available time directly affected the amount of content covered and the number of pedagogical guides completed by the end of the intervention. On average, treatment sections completed 5.56 out of the 9 guides included in the original curriculum plan. [Table 2](#) presents the number of sections according to their average weekly time allocation, as well as the final guide completed in each group. As expected, sections allocating between 90 and 120 minutes per week were able to complete the entire intervention, while those with less than 60 minutes reached, on average, up to guide 5.

Materials and methods

Sample selection

From the population of schools implementing IBE in Quechua Collao, inclusion and exclusion criteria were applied to select the participating schools. Eligible schools were those offering the Revitalization or Urban Contexts (designed to serve Indigenous migrant students in urban or peri-urban areas) service modalities – since the app was designed to promote oral and written learning of Quechua Collao among students whose mother tongue is not Quechua Collao –, and that had electricity, sufficient availability of tablets, and were located in urban areas or in rural areas within 30 minutes of the provincial capital, facilitating implementation and monitoring of the intervention. Schools were excluded if they were single-teacher schools – often operating with multigrade classrooms, which complicates implementation and data collection – or if they belonged to a UGEL with fewer than seven schools meeting the inclusion criteria.

Subsequently, phone calls were made to school principals to verify information related to the selection criteria. Of the 291 schools for which complete information was obtained, 235 met the minimum requirements to participate in the intervention. Their distribution by department was as follows: Apurímac ($n = 36$), Cusco ($n = 108$), and Puno ($n = 94$). Given the greater concentration of schools, it was decided to conduct the study in the 202 schools located in Cusco and Puno.

Randomization

Once the sample was defined, schools were randomly assigned to treatment or control groups. Randomization was stratified by UGEL and by the presence of a secondary level, to ensure geographic and educational balance. In total, 102 schools were assigned to the treatment group – receiving the Quechua Collao app and the other components of the intervention – while 100 schools were assigned to the control group and received no additional services. In schools with more than three sections within the same grade, participating sections were randomly selected due to the intervention’s capacity constraints. Within each selected section, 24 students were randomly chosen from the student roster one day prior to the school visit. Additional details of the randomization procedures are provided in Appendix A.

Assessment instruments

The main assessment instrument was a student survey administered to both treatment and control groups. The survey was conducted before the intervention, between June and August 2024 (baseline), and after the intervention, between November and December 2024 (endline). It was self-administered using a tablet and headphones provided by the enumerator during the school visit. This modality allowed participants to proceed at their own pace, thereby reducing potential enumerator bias. Since the survey included modules to assess Quechua Collao language skills, these were translated and validated by a language expert with technical support from MINEDU. The survey measured written and oral skills in Quechua, implicit and explicit perceptions of the language, its everyday use, and students’ reported experiences of discrimination.

Quechua skills

To assess students’ proficiency in Quechua, two complementary modules with distinct objectives were administered: a general Quechua skills module capturing overall language proficiency, including aspects beyond the content directly addressed by the intervention, and a OEI curriculum-aligned module designed to evaluate learning outcomes associated with the Quechua Collao app. The specific items included in both modules and the skills they measure are reported in the student questionnaire (Supplementary material 1).

The general module assessed three dimensions: speaking, listening, and reading skills, through a total of 15 items. Speaking skills (4 items) were measured by asking students to listen to questions in Quechua and respond orally in the same language. Listening skills (6 items) were evaluated through tasks involving the identification of images corresponding to audio clips and the comprehension of short oral narratives, with questions also presented in audio format. Reading skills (5 items) included exercises at two levels of difficulty: matching simple Quechua sentences to images and reading a short story in Quechua followed by multiple-choice questions (also in Quechua), assessing both basic recognition and deeper comprehension.

This general module was developed by adapting official instruments, including the Peruvian national standardized assessment administered to all second-grade students *Evaluación Censal de Estudiantes* (ECE), the Student Sociolinguistic Questionnaire from the 2011 *Niños del Milenio* School Survey (University of Oxford, n.d.), and a psycholinguistic characterization tool designed to assess oral and written proficiency in the languages spoken in the school community (Dirección General de Educación Alternativa, Intercultural Bilingüe y de Servicios Educativos en el Ámbito Rural, 2013).

The curriculum-aligned module assessed listening and reading skills only, through 11 items. Speaking skills were not included, as they were not targeted by the app. The listening section (6 items) combined audio-to-image matching and comprehension of oral stories, with questions presented in audio format. The reading section (5 items) assessed recognition of simple sentences linked to images, and reading comprehension of short texts through multiple-choice questions in Quechua. Although fully aligned with the intervention curriculum, some items were adapted from external

sources, including the ECE and a second-grade Diagnostic Reading Test developed by MINEDU (MINEDU, 2022), to reinforce and expand the range of skills practiced in the app while maintaining coherence with OEI learning objectives.

Overall scores for both modules, as well as for each skill (speaking, listening, and reading), were calculated as the percentage of correct responses, ranging from 0 to 1.

Implicit and explicit perceptions toward Quechua

Students' perceptions of Quechua were assessed using two complementary approaches: explicit and implicit. Explicit perceptions were measured by asking students to indicate their level of agreement or disagreement with a set of statements related to the use and teaching of Quechua. These statements were adapted from previous sociolinguistic studies on language attitudes (Dekker et al., 2021; Loureiro-Rodríguez et al., 2012; Zúñiga et al., 2000) and are included in the *Percepciones de la enseñanza del Quechua* module of the student questionnaire (Supplementary material 1). An Explicit Perceptions Index was constructed as the average response across items, ranging from 0 to 4, with higher values indicating more positive perceptions toward Quechua.

Implicit perceptions were assessed using a Matched-Guise design. Students listened to four recordings of the same sentence – spoken by a woman and a man in Quechua and by a woman and a man in Spanish – and then rated each speaker on 12 positive and negative characteristics. Both the audio content and the statements were adapted from Marcinko (2023) and are included in the *Matched Guise* module of the student questionnaire (Supplementary material 1). In line with the traditional Matched-Guise technique, participants were unaware that they were evaluating the same sentence across different linguistic varieties, allowing differences in evaluations to be attributed to language rather than to the speaker (Loureiro-Rodríguez & Acar, 2022).

Based on these responses, three indices were constructed: an Implicit Perceptions Index Toward Quechua (average of the 24 statements related to the two Quechua recordings), an Implicit Perceptions Index Toward Spanish (based on the two Spanish recordings), and a general Implicit Perceptions Index defined as the difference between the Quechua and Spanish scores. All indices range from 0 to 5, with higher values indicating more positive language perception. Compared to explicit measures, this approach captures more indirect and spontaneous evaluations, providing a closer approximation to students' underlying attitudes toward Quechua.

Use of Quechua

Quechua use was measured through two items. The first assessed how frequently students used the language in different public spaces (school, market or shop, hospital, pharmacy, street, and social media), community spaces (e.g., *chacra*), and at home. In many Indigenous Andean and Amazonian communities, the *chacra* (or *chakra*) refers to a multifunctional agricultural space that combines food crops with medicinal plants and serves as a center of ancestral knowledge. These chacras are not only farmland but also spaces where Indigenous knowledge and traditions are preserved and transmitted (The Food and Agriculture Organization [FAO], 2023). The second examined its use with family members (parents, older siblings, younger siblings, grandparents, and uncles/aunts) and with people in public spaces (teachers, neighbors or community members, classmates, and the school principal). Based on these items, three indicators were constructed: the Quechua Use Index, calculated as the overall average of both items; the Quechua Use in Places Index, based on reported use across different spaces; and the Quechua Use with People Index, based on reported use with different interlocutors. All indices range from 0 to 1, with higher values indicating more frequent use of Quechua.

Discrimination

Regarding experiences of discrimination, students were asked how often they had faced the following situations due to their origin, culture, or mother tongue: (1) being treated with less respect or kindness than others; (2) receiving worse service in restaurants or stores; (3) having people act as if they thought they were not intelligent; (4) having people act as if they were superior; (5) being given nicknames or

insults; and (6) being excluded, isolated, or ignored. Based on these responses, a Discrimination Index was constructed, ranging from 0 to 1, where higher values reflect a greater frequency of discriminatory experiences. This item was adapted from the Everyday Discrimination Scale (Williams et al., 1997).

Internal consistency

Cronbach's alpha coefficients were calculated for all assessment instruments. Internal consistency was acceptable to excellent across scales, with alpha values ranging from .73 to .93, exceeding the commonly accepted threshold of .70 for research purposes (George & Mallery, 2019). Alpha coefficients for the Quechua tests were somewhat lower than those observed for the attitudinal and behavioral indices, which is expected given that these tests assess multiple language skills (e.g., speaking, listening, and reading) that capture related but distinct dimensions of language proficiency. Overall, the results indicate satisfactory reliability of the instruments used in the study. Detailed reliability coefficients for each scale are reported in Appendix B (Table B1).

Internal validity

RCTs identify the causal impact of an intervention by generating comparable treatment and control groups (Duflo et al., 2007). Table 3 summarizes a set of student and teacher variables measured at baseline, together with the results of two-tailed tests for equality of means between the treatment and control groups. The sample corresponds to the schools with endline information available (200 schools), which is the sample used in the intervention impact estimates.

The results indicate that, for most variables, the student sample is balanced across treatment and control groups (see Panel A). The only exception is a slightly higher proportion of sixth-grade students in the control group. This unbalanced variable was included as a control in the main regressions (see section Statistical Models). Regarding the teacher sample (see Panel B), the balance between groups is also adequate, except for the index of explicit perceptions – where the teachers in the treatment group showed more favorable attitudes toward Quechua – and years of teaching experience, which were also higher in the treatment group.

Statistical models

To evaluate the effects of the intervention on students, the following equation was estimated using ordinary least squares (OLS):

$$Y_{ij} = \beta_0 + \beta_1 T_{ij} + \beta_2 X_{ij} + \gamma_s + \varepsilon_{ij} \quad (\text{a})$$

where Y_{ij} represents the outcome of interest for student i in school j , measured at endline; T_{ij} is a binary variable equal to 1 if the student belongs to the treatment group and 0 if the student belongs to the control group; β_1 captures the causal effect of the treatment on the outcome of interest; X_{ij} is a vector of student-level controls (grade, gender, mother tongue, whether the student learned a second language in childhood, Quechua score on the general module, Spanish reading comprehension score, and the Implicit Perceptions Index Toward Quechua, all measured at baseline) and school-level controls (IBE modality, number of enrolled students in 2023, number of active classrooms, and access to basic services such as water and sanitation); and ε_i is the error term. All specifications include stratum fixed effects (μ_s) – UGEL and educational level – to incorporate the randomization strategy into the model, thus improving estimation efficiency (Bruhn & McKenzie, 2009). Standard errors were clustered at the school level j , to account for potential intragroup correlation among students within the same school.

Following the impact evaluation literature, β_1 represents the Intention-to-Treat effect (ITT). The ITT measures the effect of an intervention on those assigned to the treatment group, regardless of whether they actually participated in the intervention. In many cases, both researchers and

Table 3. Balance of the sample at endline.

Variables	Control (C)	Treatment (T)	Difference (T-C)	p-value	N
<i>Panel A: Student characteristics</i>					
Age (years)	11.74 (0.74)	11.77 (0.76)	0.03 (0.03)	0.28	4,464
Female (%)	0.51 (0.50)	0.51 (0.50)	0.00 (0.01)	0.64	4,464
Speaks Quechua as first language (%)	0.22 (0.41)	0.20 (0.40)	-0.02 (0.02)	0.32	4,464
Sixth grade of primary (%)	0.57 (0.49)	0.53 (0.50)	-0.05** (0.02)	0.03	4,464
Has a course where Quechua is taught (%)	0.47 (0.50)	0.43 (0.50)	-0.03 (0.03)	0.60	4,464
Index of explicit perceptions toward Quechua (SD)	0.01 (1.00)	0.01 (0.99)	0.02 (0.04)	0.33	4,452
General implicit perceptions index (SD)	0.01 (0.99)	0.06 (0.95)	0.04 (0.03)	0.12	4,464
Discrimination index (SD)	-0.01 (1.00)	-0.05 (0.96)	-0.04 (0.03)	0.19	4,462
Quechua use index (SD)	-0.00 (1.00)	-0.06 (0.99)	-0.05 (0.04)	0.19	4,464
Spanish reading comprehension score (SD)	0.01 (1.00)	0.02 (1.00)	0.03 (0.04)	0.52	4,464
Overall Quechua (general module) (SD)	0.00 (1.00)	-0.02 (1.00)	-0.00 (0.05)	0.93	4,464
<i>Panel B: Teacher characteristics</i>					
Age (years)	48.92 (9.39)	49.71 (9.29)	0.93 (1.14)	0.42	280
Female (%)	0.55 (0.50)	0.59 (0.49)	0.03 (0.06)	0.61	280
Speaks Quechua (%)	0.84 (0.37)	0.85 (0.35)	-0.00 (0.05)	0.93	280
Identifies as Quechua (%)	0.67 (0.47)	0.74 (0.44)	0.07 (0.06)	0.22	280
Teaches in primary (%)	0.64 (0.48)	0.69 (0.47)	-0.01 (0.03)	0.72	280
Years of experience	18.84 (11.24)	21.04 (11.25)	2.39* (1.38)	0.08	274
Teaches the Quechua course (%)	0.46 (0.50)	0.45 (0.50)	-0.01 (0.06)	0.82	280
Index of explicit perceptions toward Quechua (SD)	-0.01 (1.05)	0.30 (0.95)	0.26** (0.13)	0.04	216
General implicit perceptions index (SD)	0.02 (1.03)	-0.02 (0.90)	-0.02 (0.12)	0.89	216
Language bias index (SD)	-0.01 (1.07)	-0.03 (0.84)	0.02 (0.14)	0.89	216
Gender bias index (SD)	0.03 (1.01)	0.05 (0.88)	-0.07 (0.15)	0.66	216
ICT perceptions index (SD)	-0.04 (1.01)	0.09 (1.14)	0.12 (0.15)	0.43	216
Quechua use index (SD)	0.01 (1.00)	0.19 (0.98)	0.09 (0.13)	0.48	216
Overall Quechua score (SD)	0.05 (1.01)	0.13 (0.97)	0.06 (0.14)	0.67	216

Notes: The p-value corresponds to a two-tailed test of equality of means between treatment and control groups. Significance levels: ***p<0.01, **p<0.05, *p<0.1. (SD) indicates that indices are standardized relative to the control group mean and standard deviation according to equation (e). The model includes stratification fixed effects, and standard errors are clustered at the school level. ICT: Information and Communication Technologies.

policymakers are interested in the impact of offering a policy or program, beyond its actual uptake, since this reflects what is likely to occur if implemented at scale. For this reason, this estimator is also referred to as the policy impact of an intervention (Gertler et al., 2016).

In addition, to estimate the Average Treatment Effect on the Treated (ATT) – that is, the effect on participants who actually received the intervention – an instrumental variables (IV) approach was implemented, in which random assignment was used as an instrument for treatment intensity (measured as the number of hours of exposure to the intervention). This follows the model proposed by Angelucci and Attanasio (2006). The method requires two stages. In the first stage, the effect of random assignment on treatment intensity was estimated using the following regression:

$$H_{ij} = \beta_o + \beta_1 T_{ij} + \beta_2 X_{ij} + \gamma_s + \varepsilon_{ij} \quad (b)$$

where H_{ij} denotes the actual number of intervention hours received by student i in school j , and the remaining variables are defined as in equation (a). Random assignment provides a valid instrument for treatment intensity as it satisfies the standard instrumental variable assumptions. First, it is strongly correlated with actual exposure to the intervention: assignment to the treatment group increased the number of hours of participation in program activities, and no school in the control group received the app, the instructional guides, or pedagogical trainer support. Second, the exclusion restriction is plausible in this context, as random assignment affects student outcomes only through its impact on exposure to the intervention; assignment itself did not modify curricula, school resources, or other educational inputs outside the program. Finally, the monotonicity assumption is satisfied, as assignment to the treatment group could not reduce students' exposure to Quechua instruction: no student assigned to treatment received fewer hours of exposure as a result of assignment, and there is no evidence of compensatory behavior that would offset participation in the program. In the second stage, the effect of the (instrumented) number of exposure hours on the outcome of interest is estimated:

$$Y_{ij} = \beta_o + \beta_1 \hat{H}_{ij} + \beta_2 X_{ij} + \gamma_s + \varepsilon_{ij} \quad (c)$$

where \hat{H}_{ij} is the predicted value of exposure hours from the first stage, and the remaining variables are defined as in equation (a). In this case, the coefficient β_1 captures the causal effect of one hour of exposure to the intervention (ATT).

Finally, to examine how the results vary according to different student characteristics, heterogeneous treatment effects are estimated. These effects are estimated by interacting the treatment variable with a characteristic of interest (e.g., the student's mother tongue):

$$Y_{ij} = \beta_o + \beta_1 T_{ij} + \beta_2 S_{ij} + \beta_3 T_{ij} S_{ij} + \beta_4 X_{ij} + \gamma_s + \varepsilon_{ij} \quad (d)$$

where S_{ij} is a binary variable representing the student's characteristic of interest measured at baseline, and $T_{ij} S_{ij}$ is the interaction between the treatment assignment and that characteristic. In this specification, β_3 represents the additional effect for the included category ($S_{ij} = 1$) compared to the omitted one ($S_{ij} = 0$). Therefore, $\beta_1 + \beta_3$ is the total ITT effect for the included group, while β_1 is the ITT effect for the omitted group.

All outcome variables in the regressions were standardized using the following formula:

$$Z_{ij} = \frac{Y_{ij} - \mu_c}{\sigma_c} \quad (e)$$

where Y_{ij} represents the outcome of interest for student i in school j ; μ_c is the mean of the control group; and σ_c is the standard deviation of the control group. Thus, Z_i is the standardized variable, expressed in standard deviations from a normal distribution with a mean of 0. Standardizing outcome variables is a common practice (Banerjee et al., 2007; Glewwe et al., 2009), as it allows intervention effects to be reported in a common unit, namely standard deviations. As a result of this transformation, the estimated ITT effect in all specifications is expressed in standard deviations (SD) of the control group.

Table 4. Students' perceptions about the app.

Desire for the app to be implemented again next year		Students' satisfaction with the app				Students' perception of the usefulness of the app				Experienced difficulties with the app			
Yes	No	Did not like it at all	Did not like it	Neither liked nor disliked it	Liked it	Liked it a lot	Not useful at all	Indifferent	Slightly useful	Useful	Very useful	Yes	No
N	2,531	189	60	73	185	1,543	859	48	59	209	988	1,416	1,560
%	93	7	2	3	7	56	32	2	2	8	36	52	57

Notes: The sample corresponds to 2,720 users interviewed at endline.

Table 5. Type of difficulty with the app reported by students.

Type of difficulty	N	%
Technical problems (e.g., app crashes, slow loading)	288	25
Difficulty understanding how to complete tasks	391	34
Problems with audio or pronunciation	375	32
Limited time to use the app	129	11
Difficulty navigating app screens/menus	94	8
Other	65	6

Source: OEI monitoring data.

Notes: Percentages do not add up to 100% because a student may report more than one difficulty. Percentages are calculated based on the 1,160 students who declared having experienced some difficulty.

Results

Two primary outcomes were specified: (1) overall Quechua proficiency measured by the general skills module, and (2) overall proficiency measured by the curriculum-aligned module, as these capture the main learning objectives of the intervention. Outcomes related to specific subskills (listening, reading, speaking), language use, perceptions, and discrimination are treated as secondary outcomes and should be interpreted accordingly.

Perceptions of the Quechua Collao app

In the endline survey, students were asked about their perceptions regarding the use of the app. Overall, the results show high levels of satisfaction and a positive perception of its usefulness. This evaluation is also reflected in the high percentage of students who expressed their desire for the app to continue being used in their school (see Table 4).

However, 43% of students reported experiencing difficulties when using the app. The most common issue was “understanding how to complete the tasks,” cited by 34% of respondents. This was followed by “problems with audio or pronunciation” (32%) and “technical problems,” such as slow loading or unexpected shutdowns of the app (25%) (see Table 5).

Quechua skills

Table 6 reports the ITT estimates of the intervention’s effect on students’ Quechua skills, measured through the general module. In both models – without controls (Column 1) and

Table 6. ITT effect of the intervention on overall Quechua score (general module) and by skills (in standard deviations).

Variables	(1) Overall	(2) Speaking	(3) Listening	(4) Reading	(5) Overall	(6) Speaking	(7) Listening	(8) Reading
Treatment (T)	0.123** (0.055)	0.064 (0.053)	0.069 (0.050)	0.174*** (0.048)	0.137*** (0.029)	0.072** (0.038)	0.087*** (0.029)	0.183*** (0.031)
Quechua score (general module) B (SD)					0.623*** (0.013)	0.492*** (0.017)	0.549*** (0.014)	0.499*** (0.015)
Spanish reading comprehension score B (SD)					0.031*** (0.013)	0.059*** (0.013)	−0.023* (0.012)	0.032** (0.013)
Observations	4,464	4,464	4,464	4,464	4,464	4,464	4,464	4,464
Number of schools	200	200	200	200	200	200	200	200
Number of strata	29	29	29	29	29	29	29	29
School-level controls	No	No	No	No	Yes	Yes	Yes	Yes
Student-level controls	No	No	No	No	Yes	Yes	Yes	Yes

Notes: SD: variable standardized following equation (e); B: variable measured at baseline. All regressions include stratum fixed effects, and robust standard errors (reported in parentheses) are clustered at the school level. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7. ITT effect of the intervention on overall Quechua score (OEI module) and by skills (in standard deviations).

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Overall	Listening	Reading	Overall	Listening	Reading
Treatment (T)	0.320*** (0.052)	0.294*** (0.053)	0.264*** (0.043)	0.330*** (0.030)	0.312*** (0.031)	0.262*** (0.031)
Quechua score (general module) B (SD)				0.517*** (0.015)	0.503*** (0.014)	0.396*** (0.018)
Spanish reading comprehension score B (SD)				0.032*** (0.012)	-0.034*** (0.011)	0.096*** (0.014)
Observations	4,464	4,464	4,464	4,464	4,464	4,464
Number of schools	200	200	200	200	200	200
Number of strata	29	29	29	29	29	29
School-level controls	No	No	No	Yes	Yes	Yes
Student-level controls	No	No	No	Yes	Yes	Yes

Notes: SD: variable standardized following equation (e); B: variable measured at baseline. All regressions include stratum fixed effects, and robust standard errors (reported in parentheses) are clustered at the school level. Significance levels: ***p<0.01, **p<0.05, *p<0.1.

with controls (Column 5) – a statistically significant improvement is observed in the overall Quechua score of 0.123 and 0.137 standard deviations (SD), with significance levels of 5% and 1%, respectively. Significant improvements are also found across specific skills: speaking, listening, and reading show increases of 0.072, 0.087, and 0.183 SD, respectively, in the models with controls (Columns 6–8).

On the other hand, **Table 7** presents the estimated ITT effect of the intervention on students’ Quechua skills as measured by the OEI module, which assesses specific knowledge directly related to the content covered in the app. Overall, skills aligned with the app improved significantly by 0.320 SD and 0.330 SD in models without and with controls, respectively (Columns 1 and 4). For listening skills, students showed improvements of 0.294 SD and 0.312 SD, both statistically significant at the 1% level (Columns 2 and 5). Similarly, significant gains were observed in reading skills, with increases of 0.264 SD and 0.262 SD, respectively (Columns 3 and 6).

To account for the effective implementation of the intervention, **Table 8** shows the results of the instrumental variables (IV) model, corresponding to equation (c), using as dependent variables the

Table 8. ATT effect of the intervention on overall Quechua scores (general and OEI modules) (in standard deviations).

Variables	(1) Overall Quechua score (general module)				(2) Overall Quechua score (OEI module)			
	OLS		IV-hours of exposure		OLS		IV-hours of exposure	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treatment (T)	0.123** (0.055)	0.137*** (0.030)	0.009** (0.004)	0.010*** (0.002)	0.320*** (0.052)	0.330*** (0.030)	0.024*** (0.004)	0.025*** (0.002)
Quechua score (general module) B (SD)		0.623*** (0.013)		0.624*** (0.013)		0.517*** (0.015)		0.518*** (0.015)
Spanish reading comprehension score B (SD)		0.031*** (0.010)		0.031*** (0.010)		0.032*** (0.012)		0.031*** (0.011)
Observations	4,464	4,464	4,464	4,464	4,464	4,464	4,464	4,464
Number of schools	200	200	200	200	200	200	200	200
Number of strata	29	29	29	29	29	29	29	29
School-level controls	No	Yes	No	Yes	No	Yes	No	Yes
Student-level controls	No	Yes	No	Yes	No	Yes	No	Yes

Notes: SD: variable standardized following equation (e); B: variable measured at baseline. The IV model corresponds to the estimation of equation (c). All regressions include stratum fixed effects, and robust standard errors (reported in parentheses) are clustered at the school level. Significance levels: ***p<0.01, **p<0.05, *p <0.1.

Table 9. ITT effect of the intervention on overall Quechua score (OEI module) by student characteristics (in standard deviations).

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Gender: Female	Grade: First year of secondary	Department: Cusco	Mother tongue: Quechua	Overall Quechua score above the median (B)	Quechua Use Index above the median (B)
<i>Panel A: Without controls</i>						
Treatment (T)	0.322*** (0.057)	0.307*** (0.067)	0.343*** (0.055)	0.347*** (0.051)	0.340*** (0.043)	0.370*** (0.053)
Subgroup (S)	0.104** (0.040)	0.297*** (0.107)	0.131 (0.210)	0.579*** (0.061)	0.884*** (0.044)	0.496*** (0.042)
Interaction (TxS)	-0.005 (0.053)	-0.004 (0.096)	-0.047 (0.101)	-0.086 (0.073)	-0.022 (0.062)	-0.072 (0.057)
<i>Panel B: With controls</i>						
Treatment (T)	0.309*** (0.037)	0.341*** (0.038)	0.346*** (0.040)	0.354*** (0.032)	0.332*** (0.035)	0.373*** (0.037)
Subgroup (S)	0.028 (0.033)	0.112 (0.070)	-0.024 (0.111)	0.227*** (0.047)	-0.061 (0.050)	0.148*** (0.030)
Interaction (TxS)	0.041 (0.045)	-0.025 (0.060)	-0.03 (0.061)	-0.119** (0.059)	-0.005 (0.050)	-0.085* (0.046)
Observations	4,464	4,464	4,464	4,464	4,464	4,464
Number of schools	200	200	200	200	200	200
Number of strata	29	29	29	29	29	29

Notes: (B): variable measured at baseline. The reported results correspond to the estimation of equation (d). All regressions include stratum fixed effects, and robust standard errors (reported in parentheses) are clustered at the school level. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

overall Quechua score (general module) and the overall Quechua score (OEI module). Odd-numbered columns report the ATT effect of the intervention without controls, while even-numbered columns include control variables. The analysis shows a positive effect of 0.009 SD and 0.010 SD on the general module score for each additional hour of exposure, in the models without and with controls,

Table 10. ITT effect of the intervention on explicit and implicit perceptions toward Quechua and Spanish (in standard deviations).

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Perceptions				Perceptions			
	Explicit	Implicit: Quechua- Spanish	Implicit: Quechua	Implicit: Spanish	Explicit	Implicit: Quechua- Spanish	Implicit: Quechua	Implicit: Spanish
Treatment (T)	0.045 (0.036)	-0.020 (0.026)	-0.002 (0.039)	0.010 (0.037)	0.037 (0.031)	-0.017 (0.026)	-0.016 (0.032)	-0.006 (0.030)
Quechua score (general module) B (SD)					-0.007 (0.018)	0.041** (0.017)	-0.067*** (0.016)	-0.090*** (0.015)
Spanish reading comprehension score B (SD)					0.293*** (0.014)	-0.003 (0.015)	0.312*** (0.015)	0.306*** (0.014)
Observations	4,403	4,464	4,464	4,464	4,403	4,464	4,464	4,464
Number of schools	200	200	200	200	200	200	200	200
Number of strata	29	29	29	29	29	29	29	29
School-level controls	No	No	No	No	Yes	Yes	Yes	Yes
Student-level controls	No	No	No	No	Yes	Yes	Yes	Yes

Notes: SD: variable standardized following equation (e); B: variable measured at baseline. All regressions include stratum fixed effects, and robust standard errors (reported in parentheses) are clustered at the school level. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

respectively (Columns 3 and 4). Similarly, a positive and statistically significant effect of 0.024 SD and 0.025 SD is found on the OEI module score for each additional hour of exposure, under both specifications (Columns 7 and 8).

Finally, **Table 9** presents the ITT effects of the intervention on the overall Quechua score (OEI module), estimated using equation (d). In Panel A (without controls), none of the interaction coefficients are statistically significant, indicating no evidence of heterogeneous intervention effects by gender, grade level, geographic location, mother tongue, Quechua skills, or students' frequency of Quechua use. In contrast, Panel B (with controls) shows significant differences in some subgroups: specifically, the interaction is negative and statistically significant for students whose mother tongue is Quechua (-0.119 SD) and for those who reported higher Quechua use at baseline (-0.085 SD). On the other hand, the results using the overall Quechua score from the general module as the outcome variable (available upon request from the authors) show no evidence of heterogeneity in the program's effect.

Implicit and explicit perceptions toward Quechua

Table 10 reports the ITT effects of the intervention on explicit and implicit perceptions toward Quechua, the latter measured through the Matched-Guise technique. Overall, the intervention did not generate statistically significant effects on students' perceptions of either Quechua or Spanish. These results are robust, as the absence of significant effects is consistent across both the models with controls and those without controls.

Use of Quechua

Table 11 shows the estimated ITT effect of the intervention on different indices related to the use of Quechua. Overall, the results indicate that the intervention had a positive effect on the frequency with which students reported using the language. In particular, a statistically significant increase of 0.123 SD and 0.144 SD was observed in Quechua use, according to the models without and with controls, respectively (Columns 1 and 7).

When the analysis is disaggregated by contexts and interlocutors, the most pronounced effects appear in public spaces (such as school, market or shop, hospital, pharmacy, street, and social media), where use of the language increased by 0.187 SD in the model with controls (Column 8). Similarly, an increase of 0.176 SD was found in Quechua use with people in public settings (teachers, neighbors or community members, classmates, and the school principal), according to the same model (Column 11). By contrast, the effects were smaller for Quechua use in the *chacra* (0.081 SD) and with family members (0.066 SD). Finally, no significant changes were observed in Quechua use within the household under any specification.

Tables 12 and **13** present the estimates of the heterogeneous ITT effects of the intervention on the Quechua Use Index in public spaces and with people in public places, respectively, based on equation (d). **Table 12** shows that the intervention's impact on Quechua use in public spaces was smaller among students in Cusco and those with higher prior proficiency in the language, as indicated by the negative and statistically significant interactions in Columns 2 and 4. In contrast, no significant differences were found by grade (Column 1), mother tongue (Column 3), or baseline Quechua Use Index (Column 5).

On the other hand, **Table 13** shows that the intervention had a smaller impact on the frequency of use of Quechua with people in public spaces among students in Cusco and those with higher baseline proficiency in Quechua, as the corresponding interactions are negative and statistically significant in both models, with and without controls (Columns 2 and 4).



Table 11. ITT effect of the intervention on the frequency of Quechua use (in standard deviations).

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Use of Quechua											
	Quechua Use Index	Public	Home	Chacra	Public	Family	Quechua Use Index	Public	Home	Chacra	Public	Family
Treatment (T)	0.123*** (0.042)	0.170*** (0.040)	-0.011 (0.036)	0.064 (0.039)	0.163*** (0.042)	0.047 (0.039)	0.144*** (0.032)	0.187*** (0.034)	0.012 (0.027)	0.081** (0.032)	0.176*** (0.036)	0.066*** (0.028)
Quechua score (general module) B (SD)							0.193*** (0.018)	0.070*** (0.018)	0.263*** (0.017)	0.219*** (0.019)	0.063*** (0.019)	0.242*** (0.017)
Spanish reading comprehension score B (SD)							-0.106*** (0.015)	-0.118*** (0.016)	-0.084*** (0.014)	-0.051*** (0.015)	-0.076*** (0.014)	-0.068*** (0.014)
Observations	4,462	4,463	4,463	4,463	4,463	4,433	4,462	4,463	4,463	4,463	4,463	4,433
Number of schools	200	200	200	200	200	200	200	200	200	200	200	200
Number of strata	29	29	29	29	29	29	29	29	29	29	29	29
School-level controls	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Student-level controls	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Notes: SD: variable standardized following equation (e); B: variable measured at baseline. Public places: school, market or shop, hospital, pharmacy, street, and social media. Public people: teachers, neighbors or community members, classmates, and the school principal. All regressions include stratum fixed effects, and robust standard errors (reported in parentheses) are clustered at the school level. Significance levels: ***p<0.01, **p<0.05, *p<0.1.

Table 12. ITT effect of the intervention on the Quechua use in public spaces by student characteristics (in standard deviations).

Variables	(1)	(2)	(3)	(4)	(5)
	Grade: First year of secondary	Department: Cusco	Mother tongue: Quechua	Overall Quechua score above the median (B)	Quechua Use Index above the median (B)
<i>Panel A: Without controls</i>					
Treatment (T)	0.198*** (0.048)	0.244*** (0.055)	0.195*** (0.041)	0.247*** (0.047)	0.188*** (0.040)
Subgroup (S)	0.312*** (0.087)	0.133 (0.131)	0.470*** (0.061)	0.299*** (0.043)	0.641*** (0.042)
Interaction (TxS)	-0.090 (0.077)	-0.139* (0.080)	-0.084 (0.086)	-0.151** (0.060)	0.006 (0.059)
<i>Panel B: With controls</i>					
Treatment (T)	0.224*** (0.045)	0.245*** (0.053)	0.208*** (0.038)	0.263*** (0.043)	0.200*** (0.037)
Subgroup (S)	0.305*** (0.076)	0.168 (0.106)	0.371*** (0.056)	0.080 (0.055)	0.546*** (0.041)
Interaction (TxS)	-0.081 (0.070)	-0.114 (0.072)	-0.099 (0.080)	-0.155*** (0.057)	-0.000 (0.055)
Observations	4,463	4,463	4,463	4,463	4,463
Number of schools	200	200	200	200	200
Number of strata	29	29	29	29	29

Notes: (B): variable measured at baseline. The reported results correspond to the estimation of equation (d). All regressions include stratum fixed effects, and robust standard errors (reported in parentheses) are clustered at the school level. Significance levels: ***p<0.01, **p<0.05, *p<0.1.

Table 13. ITT effect of the intervention on the Quechua use with people in public places by student characteristics (in standard deviations).

Variables	(1)	(2)	(3)	(4)	(5)
	Grade: first year of secondary	Department: Cusco	Mother tongue: Quechua	Overall Quechua score above the median (B)	Quechua Use Index above the median (B)
<i>Panel A: Without controls</i>					
Treatment (T)	0.195*** (0.050)	0.254*** (0.057)	0.184*** (0.041)	0.252*** (0.050)	0.204*** (0.044)
Subgroup (S)	0.320*** (0.096)	0.046 (0.130)	0.472*** (0.058)	0.332*** (0.047)	0.616*** (0.043)
Interaction (TxS)	-0.100 (0.080)	-0.170** (0.082)	-0.067 (0.081)	-0.176*** (0.063)	-0.043 (0.059)
<i>Panel B: With controls</i>					
Treatment (T)	0.218*** (0.048)	0.245*** (0.053)	0.192*** (0.038)	0.260*** (0.046)	0.207*** (0.042)
Subgroup (S)	0.285*** (0.079)	0.041 (0.090)	0.378*** (0.055)	0.128** (0.056)	0.507*** (0.044)
Interaction (TxS)	-0.093 (0.073)	-0.131* (0.074)	-0.081 (0.076)	-0.173*** (0.058)	-0.042 (0.058)
Observations	4,463	4,463	4,463	4,463	4,463
Number of schools	200	200	200	200	200
Number of strata	29	29	29	29	29

Notes: (B): variable measured at baseline. The reported results correspond to the estimation of equation (d). All regressions include stratum fixed effects, and robust standard errors (reported in parentheses) are clustered at the school level. Significance levels: ***p<0.01, **p<0.05, *p<0.1.

Table 14. ITT effect of the intervention on experiences of discrimination (in standard deviations).

Variables	(1)	(2)
	Discrimination Index	
Treatment (T)	−0.059 (0.038)	−0.049 (0.031)
Quechua score (general module) B (SD)		0.049*** (0.017)
Spanish reading comprehension score B (SD)		−0.217*** (0.014)
Observations	4,452	4,452
Number of schools	200	200
Number of strata	29	29
School-level controls	No	Yes
Student-level controls	No	Yes

Notes: SD: variable standardized following equation (e); B: variable measured at baseline. All regressions include stratum fixed effects, and robust standard errors (reported in parentheses) are clustered at the school level. Significance levels: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Discrimination

Regarding the frequency with which students reported experiencing discrimination due to their background, culture, or mother tongue, the results indicate that the intervention did not produce a statistically significant effect (Table 14). Although a reduction in the discrimination index is observed (0.05–0.06 SD), this decrease is not statistically significant in any of the estimated models.

Multiple testing correction

To account for multiple hypothesis testing across related outcomes, adjusted p -values were calculated using the Romano–Wolf stepdown procedure for the estimations presented in Tables 6, 7, 10, 11, and 14. This procedure controls the family-wise error rate (FWER) while accounting for the dependence structure among correlated outcomes (Romano & Wolf, 2005).

After the correction, the main results remain largely unchanged. Statistical significance is no longer observed for the estimated effect of the intervention on the overall Quechua score (general module) in the specification without controls (Column 1, Table 6) and for the speaking skill in the specification with controls (Column 6, Table 6). In addition, the effects on Quechua use in the chacra and with family members are no longer statistically significant in the specification with controls (Columns 10 and 12, Table 11, respectively). The corrected results are available from the authors upon request.

Discussion

This article presents the results of an experimental evaluation of a pedagogical intervention based on the Quechua Collao app, designed to strengthen writing, listening, and speaking skills in Quechua as a second language (L2) among primary and secondary students in public schools with an IBE approach in Peru.

Before discussing the main results of this study, it is important to acknowledge several limitations that should be considered when interpreting the findings. First, the intervention was implemented at a relatively small scale and focused on Quechua within a specific set of public schools operating under an IBE approach; therefore, the findings may not be directly generalizable to other Indigenous languages, curricular areas, or educational contexts with different sociolinguistic characteristics. Second, the implementation of the intervention may have varied across schools due to differences in available technological resources, local logistical conditions, teachers' levels of Quechua proficiency,

and the amount of weekly instructional time allocated to Indigenous language instruction. Finally, students may have been exposed to Quechua outside the program through family interactions, community contexts, or other school activities not captured by the study. While such exposure reflects real-world language environments, it may attenuate the estimated treatment effects by increasing Quechua use and proficiency among control-group students, thereby rendering the reported impacts a conservative estimate of the program's effect. These considerations are important for contextualizing the results and for informing future research and scale-up efforts. With these caveats in mind, the main results of this study are presented and discussed below.

In terms of learning, the intervention produced positive and statistically significant effects on the development of communicative skills in Quechua. In the general test, the intervention had an impact of 0.137 standard deviations (SD) on the overall score, with specific improvements in reading (0.183 SD), listening (0.087 SD), and speaking (0.072 SD) skills, although this latter effect is no longer statistically significant after correcting for multiple testing. In parallel, the test aligned with the app's content showed even larger effects, especially in listening (0.312 SD), followed by reading (0.262 SD). This latter difference may be attributed both to the predominantly oral nature of Quechua and to the design of the app, which incorporated a high proportion of activities centered on listening comprehension. Since both tests capture different dimensions, results should be interpreted as complementary, recognizing both the scope and the limitations of each measure.

The improvement in students' language skills is consistent with the high levels of satisfaction and positive perceptions of the app's usefulness reported by participants, beyond some technical issues that should be corrected in future versions. It is also in line with the broader literature on the effectiveness of mobile-based educational interventions, which concludes that such interventions generate positive effects across a wide range of language skills (Burston, 2015; Chen et al., 2020; Cho et al., 2018; Hassan Taj et al., 2016; Lin & Lin, 2019; Mahdi, 2017; Mihaylova et al., 2022; Sung et al., 2015). This study helps fill an important gap in that literature, since most existing evaluations focus on majority languages – mainly English – and often lack rigorous designs that include pre- and post-treatment measurements, random assignment to treatment and control groups, and sufficiently large samples.

Beyond learning outcomes, the intervention also increased the use of Quechua in public spaces outside the classroom (0.187 SD), and in interactions with people in public domains outside the family environment (0.176 SD). These results suggest that the school not only fosters the development of linguistic skills but may also contribute to legitimizing the social use of Quechua in broader contexts, challenging the predominance of Spanish in public, institutional, and educational domains (Julca Guerrero, 2000). Furthermore, this greater use of Quechua may have functioned as a mechanism that complemented the activities carried out in the classroom.

The heterogeneity analysis showed that the intervention's effects on Quechua skills, as well as on its use in public spaces and with people in public domains, were greater among students whose mother tongue is not Quechua and among those with lower initial levels of proficiency and use. These findings are consistent with the original goal of the intervention, aimed at the linguistic revitalization of Quechua. In this regard, the Quechua Collao intervention highlights the potential of technological tools – particularly apps – to contribute to the preservation and revitalization of Indigenous languages, many of which are currently threatened across different parts of the world due to global dynamics such as forced displacement, economic migration, and human rights violations faced by Indigenous communities (Galla, 2016; UNESCO, 2023).

Although no significant changes were observed in explicit or implicit perceptions of Quechua, the increase in its use in public spaces can be interpreted as a transformation in social practices and, indirectly, as a form of positive valuation. In other words, students began to use Quechua in contexts where they previously did not, which constitutes a meaningful shift in language-use patterns. Likewise, no effects were found on students' perceptions of discrimination. This latter result suggests that developing language skills and increasing the use of Indigenous languages are not sufficient, on their own, to modify the dynamics of social exclusion faced by students. Achieving this requires a comprehensive strategy that also includes actions to improve school

coexistence, strengthen training in cultural diversity, and raise awareness among teachers, students, and non-Indigenous communities to promote respect for and appreciation of Indigenous languages (UNESCO, 2025). However, the absence of statistically significant effects on attitudes and perceived discrimination may also reflect the relatively short follow-up period and limited statistical power to detect small attitudinal changes; therefore, these results should be interpreted with caution.

From an education policy perspective, the effects of the intervention are promising, as they offer a concrete alternative to address some of the challenges that limit the effective implementation of IBE in classrooms in Latin America, such as the lack of bilingual and culturally relevant learning materials and the shortage of teachers with sufficient knowledge of Indigenous languages and cultures (Santos et al., 2025). These structural limitations in teachers' profiles were evident during the intervention, given that most sessions had to be conducted by pedagogical trainers – professionals with training in IBE or experience in teaching Quechua as a second language – due to the heterogeneity in Quechua proficiency among teachers in the participating schools. This finding underscores the importance of strengthening initial training, continuous professional development, and recruitment processes for IBE teachers (Corbetta, 2021; Schmelkes & Ballesteros, 2020; Valdiviezo, 2010).

In line with this, it is important to emphasize that the positive effects of the intervention cannot be attributed solely to the use of the app. Pedagogical trainers, in their dual role as implementers and as support for teachers, were key to leading the process. Likewise, the strategy included structured pedagogical guides that, in addition to guiding the use of the app, proposed complementary activities designed to reinforce content and encourage the use of Quechua in the classroom. This integrated approach – combining technology, pedagogical support, and an adapted curriculum – was decisive for the results achieved. Consequently, any scaling-up strategy should consider these components as inseparable parts of the intervention model.

Future research should address several questions that would complement the findings of this study. First, it is necessary to evaluate the medium- and long-term impacts of the intervention, as well as its effects in contexts other than the present RCT, in order to examine the persistence of effects, scalability to other populations, and potential influence on variables such as perceptions of Quechua and experiences of discrimination. Second, further research should analyze the relative effectiveness of the different components of the intervention, since the observed effects reflect the combined impact of the app, pedagogical support, and curricular design. Finally, it is essential to generate evidence on the cost-effectiveness of the intervention compared to traditional language-teaching models, with the goal of determining its scalability and long-term sustainability.

Note

1. Examples of these applications can be found in OEI (n.d.) for Bolivia, Corporación Nacional de Desarrollo Indígena (2025) for Chile, MINEDU (n.d.) for Peru, and FirstVoices (n.d.) for English-speaking countries such as Australia, Canada, the United States, and New Zealand. Artificial intelligence-based initiatives for Indigenous language preservation also exist (UNESCO, 2025). For example, LATAM-GPT is an open-source large language model (LLM) developed in Chile that incorporates Indigenous languages and reflects Latin America's cultural diversity.

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Author contributions

CRedit: **Emma Näslund-Hadley**: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing; **Juan Manuel Hernández-Agramonte**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing; **Humberto Santos**: Conceptualization, Methodology, Supervision, Visualization, Writing – original draft, Writing – review & editing; **Hugo Us**: Conceptualization, Supervision, Writing – review & editing.

Data statement

The data supporting this study's findings are available from the Inter-American Development Bank (IDB). However, access is restricted because they contain personal information on children and adolescents whose participation was authorized by their parents; therefore, the data are not publicly available. They can, however, be obtained from the authors upon reasonable request and with the permission of the Ministry of Education of Peru (MINEDU).

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendices

Appendix A. Randomization of sections and students

A.1. Sections

Table A.1. Criteria for section randomization.

Type of school	Number of sections	Type of randomization
Single-level school (primary or secondary)	Up to 3 sections across sixth grade of primary or first grade of secondary	No randomization. All available sections are selected.
	More than 3 sections across sixth grade of primary or first grade of secondary	Simple random selection of 3 sections.
Two-level school (primary and secondary)	Up to 3 sections across sixth grade of primary and first grade of secondary	No randomization. All available sections are selected.
	More than 3 sections across sixth grade of primary and first grade of secondary	Random allocation into two equally sized groups: (1) schools where 2 sections of sixth grade and 1 section of first grade are selected; and (2) schools where 1 section of sixth grade and 2 sections of first grade are selected.

A.2. Students

The selection of students was carried out using the class roster of each section included in the survey, ordered alphabetically. First, female students were selected through a systematic sampling procedure from top to bottom: the first student was selected, the second skipped, the third selected, and so on, until reaching the required number of female students (including replacements). The same procedure was then applied to male students, but in reverse order—that is, from bottom to top: the last student was selected, the second-to-last skipped, the third-to-last selected, and so forth, until completing the required number of male students (including replacements).

The number of students selected per section depended on the total number of sections to be surveyed in each school. Table A.2 presents the different scenarios identified. If the school had only one section, 24 students were surveyed from that section. In the case of two sections, 12 students were surveyed from each. For three sections, 8 students were surveyed from each section. In addition, two replacements were selected per section (one male and one female). The figure of 24 students per section was determined based on a power calculation to establish the required sample size to detect a minimum detectable effect (MDE) of 0.15 standard deviations in the outcome variables. The calculation assumed a design with 200 schools (100 in the treatment group and 100 in the control group) and considered different intraclass correlation (ρ) scenarios, ranging from 0.08 to 0.12. The results of the analysis indicated that it was necessary to survey approximately 22 students per school to achieve 80% statistical power. A slightly larger sample size (24 students) was chosen to provide an additional margin for potential data loss or student absences.

Furthermore, the number of students selected in each section was distributed equally between female and male students, adjusting to the actual availability of each gender within the section. For example, if the number of male students was lower than required to maintain the desired proportion, all available male students were included, and the remaining sample was completed with female students until reaching the expected total. The same procedure was applied in reverse when the number of female students was below the expected figure. This strategy ensured gender balance as much as possible while respecting the actual composition of each section.

Table A.2. Criteria for student randomization by school.

Scenario	Number of sections to be surveyed	Students to be surveyed per section			Total replacements	Total
		Total	Male	Female		
Scenario 1	1	24	12	12	2	26
Scenario 2	2	12	6	6	4	28
Scenario 3	3	8	4	4	6	30

Appendix B. Internal consistency of assessment instruments**Table B.1.** Summary of reliability measures.

Scale	Number of items	Cronbach's Alpha coefficient (standardized items)	Average interitem correlation
Quechua Score (general module) (Speaking: 4, Listening: 6, Writing: 5)	15	0.82	0.23
Quechua Score (OEI module) (Listening: 6, Writing: 5)	11	0.73	0.20
Explicit Perceptions Index	14	0.78	0.20
Implicit Perceptions Index (Quechua) (12 traits x 2 voices = 24 items)	24	0.93	0.36
Implicit Perceptions Index (Spanish) (12 traits x 2 voices = 24 items)	24	0.93	0.37
Quechua Use Index (Places: 8, People: 9)	17	0.91	0.36
Discrimination Index	6	0.84	0.46

Source: Authors' own calculations based on the study sample.