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Validation of hearing screening procedures in Ecuadorian schools

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3ie International Initiative for Impact Evaluation

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Abstract

Objective of evaluation study

When not detected early in life, most children with permanent hearing loss lag behind their peers in language, social and cognitive development; fail at school more frequently; and do not acquire the skills to be successfully employed. In 2012, Ecuador launched a national initiative, Tamizaje Auditivo Escolar, to identify and provide services to children with permanent hearing loss. The purpose of this evaluation, funded by the International Initiative for Impact Evaluation (3ie) in collaboration with Ecuador's Vice President's Office, the Office of the Technical Secretary of Disabilities, the Ministry of Education and the Ministry of Health, was to evaluate the accuracy and effectiveness of the teacher-administered hearing screening questionnaire used in this initiative.

Study design

The following data were collected and analysed:

1. Results from a teacher-administered hearing screening questionnaire were compared with pure tone audiometry data collected at the same time for 4,800 first-grade children in 117 schools.
2. Anonymous questionnaires were completed by teachers about their perceptions of the Tamizaje Auditivo Escolar programme.
3. Parents and teachers participated in focus groups in which they discussed the strengths and weaknesses of the Tamizaje Auditivo Escolar programme.
4. Costs of the Tamizaje Auditivo Escolar programme were estimated based on observations of the programme and interviews with programme administrators, teachers and parents.

Primary results

The teacher-administered questionnaire was inefficient for identifying children who are deaf or hard of hearing. There was little agreement between the teacher-administered questionnaire and the results of the audiometry. Approximately 80 per cent of the children who failed the hearing screening questionnaire passed the audiometry; and 85 per cent of those who failed the audiometry passed the hearing screening questionnaire. Of the 562 children who were referred for an audiological diagnostic evaluation during Phase 2 of the project, only 56 per cent completed an audiological diagnostic evaluation within the three-month time period required by the study. Of those children, 27 were diagnosed with permanent hearing loss. Of the 27 children diagnosed with hearing loss, 24 (89%) had failed audiometry, but only 6 (22%) had failed the hearing screening questionnaire. The teacher-administered hearing screening questionnaire passed too many children who had hearing loss and failed too many children who had normal hearing.

Relatively few children with hearing loss were identified. Based on the available data from the 2012 implementation of Tamizaje Auditivo Escolar, only 155 children with permanent hearing loss were identified among the 428,072 children screened—a prevalence of 0.36 children with hearing loss per 1,000 children screened. This is a substantially lower prevalence than expected and suggests that the Tamizaje Auditivo Escolar programme failed to identify more than 90 per cent of the children with permanent hearing loss in this cohort.

Teachers believed that hearing screening was important. Almost all of the teachers (97%) believed that hearing screening was very important. Many said they paid closer attention to students as a result of participating in the hearing screening programme. However, only 41 per cent of the teachers thought that the results from the screening questionnaire were 'very accurate' and only 28 per cent felt 'very well trained' to administer the questionnaire.

The Tamizaje Auditivo Escolar programme was relatively inexpensive. The average cost of the questionnaire-based screening programme was US$2.75 per child, which is very modest. Unfortunately, an inexpensive procedure is not a good investment if it doesn't identify the correct children, as was the case in this study.

Parents supported the hearing screening programme. Parents in the focus groups reported that they were unclear about the hearing screening process. They felt that school principals and healthcare providers were also unclear about what to do when a child did not pass the screening. Parents and teachers also said there were challenges and significant financial expenses to the family in accessing health services when a child failed the questionnaire-based hearing screening. Nonetheless, most parents and teachers were very supportive of the school hearing screening programme.

Findings relevant to policy and future research

The implementation of the Tamizaje Auditivo Escolar programme demonstrated a clear commitment by the Ecuadorian government to identify and help children who are deaf or hard of hearing and their families. The most important conclusions from the evaluation are summarised below:

- Implementation of Tamizaje Auditivo Escolar helped teachers identify ways in which they can support children who have difficulty hearing.
- Parents and teachers supported the goals of Tamizaje Auditivo Escolar.
- Too many children with normal hearing failed the hearing screening questionnaire, which resulted in costly follow-up testing that was often difficult for families to complete.
- Too many children with hearing loss passed the hearing screening questionnaire, which meant that these children and their families often did not receive the help they needed for the children to succeed in school and daily living activities.

- Although screening audiometry was initially thought to be too expensive for nationwide implementation, it should be reconsidered. Emerging screening technologies such as smart phone apps should also be considered.
- Too many children who failed screening never completed diagnostic audiological testing. A more effective tracking system is needed.
- Regardless of which screening methodology is used in the future, more attention needs to be paid to ensuring that the protocols and procedures are followed, and that children who fail screening are more closely followed, with support provided to families to ensure appropriate diagnosis and treatment.

Continued use of a teacher-administered hearing screening questionnaire will identify some children, but will miss many others. If the teacher-administered hearing screening questionnaire is continued, there needs to be an emphasis on systematic and structured training of teachers, better adherence to protocols and procedures, reducing loss to follow-up, and ensuring access to good diagnostic services. As an alternative, audiometry more accurately identified children with hearing loss. Despite the initially higher cost of audiometric screening, the greater accuracy in correctly identifying children with hearing loss resulted in a lower cost per diagnosed child than in the case of the teacher-administered questionnaire. In the long run, audiometric screening would likely reduce family and societal costs given appropriate diagnosis and treatment of hearing loss.

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Abbreviations and acronyms

NHS	newborn hearing screening
SETEDIS	Office of the Technical Secretary of Disabilities

1. Introduction

Improving access to services and education for individuals with disabilities, including children with hearing loss, is a key policy challenge for Ecuador. On 30 March 2007, Ecuador signed the Convention on the Rights of Persons with Disabilities with the purpose of bolstering the protection of human rights of people with disabilities. At that time, the president of the Republic, Rafael Correa, declared the care and prevention of disabilities to be Ecuador's policy. He delegated the implementation of the new law to the Office of the Vice President. According to findings from the *Misión Solidaria Manuela Espejo Bio-Psycho-Social Study*, conducted by the Office of the Vice President in 2010, hearing disability was found to have the third highest incidence of occurrence among disabilities in Ecuador. As a result of this national study, an initiative to screen the hearing of newborns, preschoolers, and school-aged children was launched in 2011. The initiative for school-aged children is known as Tamizaje Auditivo Escolar.

Having a systematic mechanism to provide low-cost hearing screening during childhood is critical for optimising future academic and vocational success for children with hearing loss. Disabling childhood hearing loss is a global problem. According to recent statistics, there are 160 million children with mild or greater hearing loss (Olusanya and Newton 2007; WHO 2013). Approximately 90 per cent of children with hearing loss are found in developing countries. This is because, as the gross national income increases, the prevalence of hearing loss decreases (Swanepoel 2013; WHO 2013). Early identification of hearing loss through newborn screening is becoming more common in developed countries; however, it is not common in developing countries. More than 90 per cent of children born with hearing loss in developing countries are not likely to be identified early. Childhood hearing loss negatively impacts speech-language, social-emotional and cognitive development. In countries where there is limited access to hearing healthcare, children often become isolated and have a reduced quality of life.

The purpose of this study was to evaluate the accuracy and effectiveness of a teacher-administered hearing screening questionnaire developed in Ecuador for use with school-aged children attending public schools. Approximately 20 per cent of the population in Ecuador is highly affluent (Knoema Data Atlas 2013), and school-aged children from these homes attend private schools and access private medical clinics. In these medical clinics, hearing screening is usually conducted during routine health visits. However, less affluent families receive health services at public clinics where hearing screening is less likely to be conducted. Hence, the Tamizaje Auditivo Escolar programme was designed for public schools with the aim of increasing the likelihood that these children would be screened for hearing loss.

The study has relevance beyond Ecuador because the importance of early identification of hearing loss is recognised around the world (WHO 2014). The challenge for developing countries is how to provide population-based hearing screening in a cost-efficient manner to those least able to afford care in private clinics. Use of questionnaires to identify hearing loss is attractive for developing countries because there are no equipment costs and minimal training requirements (e.g. Newton *et al.* 2001). However, there is lack of

evidence about the effectiveness of a screening questionnaire in accurately determining which children may have hearing loss and need further testing, and which children have normal hearing. Costs and consequences associated with potential over-referral using a questionnaire are relevant concerns for many people, as are costs and lack of successive services due to under-referral.

Findings from studies that have used questionnaires to screen children's hearing have been mixed, with some recommending (e.g. Samelli, Rabelo and Chaparin 2011) and others not recommending the use of a questionnaire (e.g. Li, Driscoll and Culbert 2009). There is no standard approach to screening children for hearing loss using a questionnaire. For example, Newton *et al.* (2001) screened preschool-aged children in Kenya (M = 5.2 years; N = 735) using an eight-question instrument designed to identify bilateral hearing loss of a moderate degree or worse based on questions that addressed behavioural reactions to sound. An ear-nose-throat physician evaluated the same children and pure tone audiometry was completed for each child. Twenty-six per cent of the children failed the questionnaire, and 13 were subsequently identified with a bilateral hearing loss, 11 of whom had severe-to-profound degrees of hearing loss. Therefore, the researchers stated that the questionnaire may be potentially useful for identifying hearing loss and could be used in community health clinics. In contrast, Li, Driscoll and Culbert (2009) developed the Chinese Hearing Questionnaire for School Children that included 11 yes/no questions related to risk indicators for hearing loss to identify children who had otitis media and/or a moderate hearing loss or worse in one or both ears. The performance of the parent-administered instrument was evaluated among children attending a rural school (M = 9.2 years; N = 154) by comparing questionnaire results to a hearing assessment battery that included pure tone audiometry, tympanometry and pneumatic otoscopy. Twelve per cent of the children failed at least one component of the audiometric test battery and 47 per cent failed at least one item on the questionnaire. The researchers concluded that the questionnaire had moderate sensitivity (0.67) and poor efficiency (0.56), and did not recommend its use for mass screening.

The Ecuadorian government launched a programme in 2012 to screen the hearing of all school-aged children (5–9 years) attending public schools using a teacher-administered questionnaire. The Office of the Vice President developed the questionnaire and procedures for its administration. They believed the questionnaire was meeting their needs; however, they wanted data about its effectiveness to inform policy, if needed. Therefore, the purpose of our study was to evaluate the effectiveness and accuracy of the teacher-administered hearing screening questionnaire by comparing the results of the questionnaire with the results of pure tone audiometry administered by trained healthcare professionals—a method that is acknowledged throughout the world as the 'gold standard' method for doing hearing screening of children (Bamford *et al.* 2007; AAA 2011; British Society of Audiology 2011). The intent of the study was not to provide data on how a viable alternative could be done because at the time the study was initiated this was not something the Ecuadorian government wanted. In the course of the study, however, it was necessary to address the procedural aspects of their screening process.

1.1 Fidelity to 3ie proposal

The following five questions were included in the original proposal to 3ie.

1. How effective is Ecuador's teacher-administered hearing screening questionnaire programme as evidenced by the percentage of children in each of the four cells in the following table?

		Results of standard audiometric screening: FAIL	Results of standard audiometric screening: PASS
Results of questionnaire-based hearing screening	FAIL		
	PASS		

2. What percentages of children who 'fail' the teacher-administered hearing screening questionnaire complete a diagnostic evaluation at a local health facility within three months?
3. How satisfied are teachers and parents with the hearing screening and referral procedures being used in Ecuadorian schools?
4. Are the answers to any of the previous questions different for families living in different regions (highlands, coastal or Amazon), different socio-economic circumstances, or urban versus rural locations?
5. What are the costs associated with the hearing screening and referral processes? In particular, what are the costs to families and the Ecuadorian health system associated with referring children for diagnosis when children are incorrectly identified with hearing loss?

These questions were all addressed throughout the course of the study, and the findings are described later in this report.

1.2 Impact evaluation design

This study was never designed to be a true 'impact evaluation' as defined in the following statement from 3ie:

> Analyses that measure the net change in outcomes for a particular group of people that can be attributed to a specific program using the best methodology available, feasible and appropriate to the evaluation question that is being investigated and to the specific context.

Instead, the original proposal made it clear that the purpose of the study was to evaluate the accuracy and effectiveness of the teacher-administered hearing screening questionnaire for 6-year-old children attending public schools in Ecuador. Although the study was not designed to be an impact evaluation as defined by 3ie, it clearly had important policy

implications—particularly in light of the commitment made by Ecuador's national government to improve outcomes for people with disabilities. The study included four components:

1. comparison of results from the teacher-administered hearing screening questionnaire to results of hearing screening with audiometry;
2. teacher feedback about the questionnaire screening process;
3. parent and teacher feedback about their experiences with the hearing screening programme; and
4. cost analysis of the screening process being used in the Tamizaje Auditivo Escolar programme.

The study was completed in two phases because children living in the coastal areas followed a different school schedule than children living in the highland and Amazon areas. In this way, we were able to include children from all regions of the country in the sample. Having two phases also provided the opportunity to learn from the Phase 1 data and make modifications to the screening processes for Phase 2. Therefore, in addition to our research questions, process components were addressed and included in this report for the purpose of providing the Ecuador government with meaningful information to consider as they make decisions about school hearing screening. Ecuadorian stakeholders (e.g. officials from the Vice President's Office, the Ministry of Education, Ministry of Health, staff from the Secretaria Tecnica de Discapacidades (Technical Secretary for Disabilities) (SETEDIS), public health doctors, public school principals and teachers, and parents) were involved in the process during the study (January 2013–December 2013).

1.3 Overview of the report

This report provides findings for all components of the study. In addition to comparing the hearing screening outcomes for the teacher-administered questionnaire and the screening audiometry, Phase 1 results include a summary from the teacher feedback questionnaire and an analysis of outcomes from the questionnaire screening completed in 2012, the first year that Tamizaje Auditivo Escolar was implemented in Ecuador and prior to the start of the 3ie-funded study. Phase 2 results include a comparison of screening outcomes (i.e. questionnaire and audiometry) and a summary of the teacher feedback questionnaire. Focus group findings were completed and reported with teachers who participated in the screening process and with parents of children who failed the screening. Focus groups conducted during Phases 1 and 2 included teachers and parents whose children were screened in 2012 and during Phase 1 of the study, respectively. A cost analysis was also done as a part of the study.

2. Intervention, theory of change and research hypothesis

This study was designed to evaluate the accuracy and effectiveness of the teacher-administered hearing screening questionnaire. To do this, children who were screened using the questionnaire were also tested with audiometry. Children who failed the questionnaire

or the audiometry were referred for further evaluation of their hearing. Ecuador had an infrastructure in place for providing hearing screening oversight by physicians for all regions of the country. These physicians were trained in the use of the screening audiometers and were also trained in the study procedures (described later). A representative of the Ecuadorian government provided teachers with training in the administration of the questionnaire screening.

2.1 Theory of change

This study evaluated the accuracy and effectiveness of using a teacher-administered questionnaire for conducting hearing screening of school-aged children enrolled in public schools. The policymakers in Ecuador had already implemented a school hearing screening procedure, and needed data to determine the efficacy of their approach. They were collaboratively involved in the design and implementation of the study. They expressed a desire to investigate the questionnaire; they were not interested in considering the use of another approach for screening during the course of the study. Therefore, the desired result of this study was to provide data about the effectiveness of the questionnaire to the Ecuadorian government to inform their decisions about the use of the questionnaire to screen the hearing of school-aged children enrolled in public schools.

The primary research hypothesis, examined as part of the evaluation, was that the teacher-administered hearing screening questionnaire was an effective means of identifying children in need of further evaluation of their hearing. The primary outcome of this study was the comparison of the results of the teacher-administered questionnaire with the results of testing with audiometry. The impacts of interest to the Ecuadorian government included the number of children incorrectly referred or not referred for further audiological diagnostic testing as a result of the teacher-administered hearing screening questionnaire.

Because staff in the Vice President's Office had invested so heavily in the development of the teacher-administered questionnaire to identify hearing loss, there was a possibility that the results of the evaluation would not be viewed positively unless the results supported the use of the teacher-administered questionnaire for hearing screening. This was particularly concerning because of the perceived need of key stakeholders for a low-cost solution and the strong commitment of the Ecuadorian government to the use of a questionnaire. These concerns were amplified by the fact that similar questionnaires used in other countries to identify hearing loss among young children have not been very successful (Hammond *et al.* 1997; Gomes and Lichtig 2005; Li, Driscoll and Culbert 2009). There are differences between the approach being used by Ecuador and those used in other countries (e.g. Ecuador was using a teacher-administered questionnaire, while most other studies have used parent interviews). Because of these factors, active involvement on the part of the government was important so they would have ownership of the findings and use the data when making policy decisions. Engagement strategies used during the study included frequent communication, input-based study planning and collaborative implementation of study activities. The assumption was that through collaborative decision making, data collection and review of findings, government officials in Ecuador would be prepared to

accept the findings (whatever the results), thus enabling them to recognise and consider changes in policy that were suggested by the data from the study.

The Ecuadorian government initially assigned policy oversight of hearing screening to the Vice President's Office. Following elections in May 2013, responsibility for the study was shifted to the newly created SETEDIS office. Staff in SETEDIS who were involved with the study had previously worked in the Vice President's Office, where also they had been working on the study. Personnel in SETEDIS are dedicated to the identification of childhood hearing loss. Given their high interest in providing hearing screening to children in Ecuador, their previous involvement in designing and implementing the Tamizaje Auditivo Escolar programme, and their ongoing efforts to support early identification and treatment of hearing loss among children, we were confident that the findings from this study would be valuable as SETEDIS moved forward with making decisions about how best to identify hearing loss among young Ecuadorian children in public school programmes. A summary of the intermediate outcomes and impact that were provided to staff in the Vice President's Office is provided in Table 1. The final outcomes and impact at the conclusion of the study are summarised in Table 2.

Table 1 Summary of intermediate outcomes and impact

Intermediary
Outcomes Poor agreement between the questionnaire and audiometry: • 3,022 students screened • 89% who failed the hearing screening questionnaire passed the audiometry • 85% who failed audiometry passed the hearing screening questionnaire Low number of children identified with hearing loss from 2012 screening reported to the Vice Presidency: • 15,061 (3.5%) were documented to have failed the hearing screening questionnaire • Of these, only 911 had follow-up testing data available • 155 of the 911 were identified with a hearing loss (an incidence of only 0.36 per 1,000 children) Feedback from 178 teachers indicated that improvement was needed in the screening process: • 97% believed that hearing screening is important • 37% believed that the questionnaire results were very accurate • Only 27% felt they were well trained to perform the screening **Impact** Format of hearing screening questionnaire improved: • Modifications made based on results from Phase 1, further literature review and pilot testing Procedure for referral, tracking and follow-up improved: • New tracking forms created • Roles, timeframes and reporting procedures defined Teacher training improved: • Instructions simplified and included on screening form • Training provided at time of screening

Table 2 Summary of final outcomes and impact

Final Outcomes and Impact
Outcomes Poor agreement between the questionnaire and audiometry (Phase 2): • 1,594 students screened • 71% who failed the hearing screening questionnaire, passed the audiometry • 85% who failed audiometry, passed the hearing screening questionnaire Many children who failed the screening were lost to follow-up: • 44% of the children were not documented as having received the recommended diagnostic testing Questionnaire did not function well in identifying children with hearing loss: • Of the 27 children identified with hearing loss in Phase 2, 89% had failed the audiometric screening, but only 22% had failed the teacher questionnaire screening Feedback from 71 teachers indicated that improvement was needed in screening process: • 99% thought hearing screening was very important • 32% felt well trained • 60% felt the teacher-administered questionnaire screening results were very accurate **Impact** Government officials recognised the limitations of the questionnaire, and the importance of having data to help guide them with their decisions about hearing screening policy • Alternative approaches were identified • Ways to improve the use of existing resources were discussed

The approach and timeline for implementing the changes identified as a result of the findings from the evaluation will depend on the availability of resources and other priorities within the Ministries of Education and Health. SETEDIS is responsible for being the liaison for ongoing work related to hearing screening in public schools and to make recommendations to the other ministries for implementation.

3. Larger context and sample context

Sampling procedures for the children included in the analysis of data obtained from the initial implementation of Tamizaje Auditivo Escolar during 2012 included public schools from all 24 provinces in Ecuador. Schools were selected based on accessibility and enrolment of more than 200 students, when possible. The selection included both Spanish and bilingual, and both urban and rural public schools. During the first year of the screening programme (prior to the implementation of the study funded by 3ie), 428,072 first- to third-grade children throughout Ecuador were screened using the teacher-administered questionnaire between April and December 2012. Children who did not pass the hearing screening were referred for additional audiological testing at the local health department. All nine zone physicians monitored the process, collected data on screening outcomes, and sent data to the Office of the Vice President.

Because screening was conducted with all early grades during 2012, study activities implemented during 2013 with funding from 3ie included only those students who were newly enrolled in 2013, e.g. rising first graders. The evaluation study included a sample of up to 50 first-grade children randomly selected from each of 128 randomly selected public schools that were included in the original hearing screening project, stratified by province to include all regions of the country. Additional bilingual schools with fewer than 200 students were also included to ensure adequate representation in the study of children enrolled in bilingual schools. These children were largely from Quechan homes, i.e. the native peoples of Ecuador. The number of bilingual schools selected approximately represented the proportion of the population of school-age children who attend school in the elementary grades.

The Ecuadorian government deemed the schools included in the study as capturing a representative sample of the majority of children in public schools in Ecuador. Because the Tamizaje Auditivo Escolar programme was still relatively new, the Office of the Vice President decided they did not initially want to include schools in the more remote, less accessible regions of the country for this study. Therefore, individuals living in remote areas of the country were not included, and challenges specific to their geographical locations are not represented. Children in the remote regions are more likely to be Quechan, live in the lowest-income households, and have the least access to modern medical care.

4. Linking programme implementation and impact evaluation timelines

Data were collected for the study from February to December of 2013 as shown in Table 3.

Table 3 Timeframe for validation study and events during study period

Activity or event	Timeframe
Initial meeting to discuss study plan	October 2012
Phase 1 meeting and training in Ecuador	February 2013
Phase 1 data collection	February–March 2013
Preliminary report provided to Vice Presidency	April 2013
Elections in Ecuador	April 2013
Focus groups	May 2013
Changes in structure of Ecuadorian government	May–July 2013
Phase 2 planning	June–August 2013
Phase 2 meeting and training in Ecuador	September 2013
Phase 2 data collection	September–December 2013
Focus groups	December 2013
Final meeting in Ecuador	February 2014

5. Methodology: evaluation design and implementation

The evaluation strategy for this study included a comparison between the questionnaire screening results and audiometry results. Children who failed either the screening questionnaire or the audiometry (or both) were referred for further audiological diagnostic testing.

5.1 Sample size

The main goal of the evaluation study was to determine if the teacher-administered hearing screening questionnaire identified the same children with hearing loss as identified by a standard audiometric screening instrument. The sample size necessary to achieve 80 per cent power to detect differences of two proportions of 10 per cent versus 15 per cent with a two-tailed test of statistical significance with α = .05 was calculated at 1,371 based on the following formula (see Eng [2003] for more detail):

$$N = 2 \bullet \frac{\left[z_{crit}\sqrt{2\,\bar{p}(1-\bar{p})} + z_{pwr}\sqrt{p_1(1-p_1)+p_2(1-p_2)}\right]^2}{D^2}$$

Given that we wanted to draw conclusions about the accuracy of the screening procedure in each of three different regions of the country, we needed about 1,400 children in each region or a total sample size of about 4,200 children. Thus, a sampling plan was developed

in which 128 public schools were selected with an anticipated maximum sample size of 50 children in each school. Because some schools had fewer than 50 first-grade children enrolled, a larger sample of schools was included. Schools and children were randomly selected from institutions where more than 50 children were enrolled. In addition to determining the sample size to meet power requirements for the primary goal of the study, there were other considerations for sample sizes to obtain supplementary data for the study (described in the section on sampling design below).

Sample #2: Comparison group from initial implementation. To determine if conducting an evaluation study changed rates of referral for the teacher questionnaire, results from Phase I of the study for the teacher questionnaire were compared to the questionnaire screening results from 2012.

Sample #3: Comparison group implementing teacher questionnaire based screening only. To further explore if conducting an evaluation study changed rates of referral on the teacher-administered questionnaire, all first-grade children in a sample of 10 schools in Quito were screened using the teacher questionnaire only. This was a convenience sample selected by the Ministry of Health from public schools with more than 200 students.

Sample #4: Teacher and parent focus groups. Samples of teachers and parents who had participated in the 2012 implementation of Tamizaje Auditivo Escolar were purposefully selected to participate in focus groups during Phase 1 held in Quito, Esmeraldas and Loja (cities in which large numbers of schools implemented the screening process in 2012). These focus groups were held to determine teacher and parent satisfaction with the hearing screening process conducted in 2012 and to explore follow-up processes. Teachers and parents in these focus groups represented urban and rural settings, and bilingual and Spanish schools. Teachers and parents for the Phase 2 focus groups were selected similarly from public schools that participated in the Phase I screening.

5.2 Sampling design

To obtain a sample of children for the comparison of the hearing screening questionnaire to standard screening audiometry, a random sample of 128 schools that had previously participated in Tamizaje Auditivo Escolar were selected in each province in proportion to the number of schools in that province. Except as noted below, schools with fewer than 200 children were excluded from the sample, and schools in both urban and rural areas as well as Spanish and bilingual schools were included.

To increase the probability that teachers in the study sample would have experience with administering the hearing screening questionnaire, only schools that participated in 2012 were considered for inclusion. Additional bilingual schools with fewer than 200 students were also included to ensure proportional representation of bilingual children enrolled in these schools. A sample of up to 50 first-grade children was randomly selected from each of the randomly selected schools. If fewer than 50 first-grade children were enrolled, all first-grade children in attendance on the day of screening were included. Children in the sample were assessed with both the teacher-administered questionnaire and audiometric screening

on the same day. Due to differing school calendar year schedules within the country, Phase 1 included students in the Amazon and highland regions and Phase 2 included students in the coastal regions.

Collecting comparative data about hearing screening in public schools was deemed the most efficient way to screen large numbers of children in a day. However, school-based screening has several limitations. First, children with hearing loss may be kept at home or, in urban areas, enrolled in a school for children with disabilities. Second, attendance across various days of the week may be selectively different, meaning that on a specific day of the week during which screening was conducted, children in attendance may not be representative of the population of the school. For example, on a mid-week market day, parents may need children to assist with getting produce to market and children may consistently miss school on market days. Finally, socio-economic status could differentially affect school attendance. However, because public schools in Ecuador predominantly serve children from less affluent homes as noted earlier, children within a school catchment area would most likely be from similar income households.

5.3 Data collection

Teacher-administered hearing screening questionnaire. The classroom teachers administered the questionnaire after the children had been in class for at least one month. Results were recorded for each child on a separate form that included the name, age and year in school of the child; the name of the teacher and the school; and the date of the screening test. Teachers were blind to the audiometric results. They did not have a stake in the outcome; however, there was a tendency for teachers to want to include more than the 50 randomly selected children, especially if they had concerns about a child who was not randomly selected to be in the study.

Audiometry. Trained Ecuadoran zone physicians and audiologists used a portable audiometer to measure responses to pure tone air conduction stimuli. Standard audiometric screening procedures (e.g. raise hand when the sound is heard) were used. To ensure that environmental noise was minimised, audiocups were used to cover the headphones. Audiometric screening data was collected on the same day that the teacher completed the hearing screening questionnaire. Screening results were recorded on a form provided by the research team. Physicians and audiologists were blind to the questionnaire screening results. Physicians and audiologists did not have a stake in the screening. They did not know the children, or have a role in the follow-up testing of children who failed the screening.

Teacher satisfaction. First-grade teachers who performed the questionnaire-based hearing screening at each of the public schools selected for the study completed a short, anonymous questionnaire about the hearing screening activities done for the study. Questions addressed the adequacy of their training, perceptions about the value of hearing screening, suggestions for improvement, strengths of the process, and barriers to implementing the Tamizaje Auditivo Escolar programme.

Teacher and parent focus groups. In May (during Phase 1) and December (during Phase 2) of 2013, focus groups were conducted with small groups of teachers and parents to discuss their perceptions and opinions about the hearing screening process and follow-up for children who needed additional diagnosis and treatment. There were four groups of teachers and three groups of parents during Phase 1, and two groups of parents and two groups of teachers in Phase 2.

Cost data. Cost data were collected from parent focus groups and from the Office of the Vice President to explore the wages of personnel involved in the screening process; the cost of materials; and costs to parents such as travel, expenses and lost wages.

6. Programme design and implementation

The key programmatic activity was the hearing screening. Zone physicians were instructed to schedule the hearing screenings so that both the teacher-administered hearing screening questionnaire and the audiometry could be completed for each child on the same day. Teachers who performed the screening with the questionnaire also completed a survey to obtain their feedback about the screening process at the conclusion of the screening activity on the same day the screenings were done. The zone physician collected all completed forms for each school. A coordinator from the Vice Presidency monitored the completion of the screenings. Physicians submitted the completed screening forms in a packet that was provided to them to the Office of the Vice President, who then sent the unopened packages to the researchers using DHL mail delivery. This system allowed the researchers to monitor progress with completion of the data collection. The protocols provided to the physicians had detailed instructions and did not require on-the-spot innovations in order to complete data collection.

Participation in the study was completed as designed because the students were selected for screening on the day the screenings were done. Therefore, students not at school on the screening day were not included in the study. The students included in the study matched the intended target population well. The study targeted children in the first grade in public schools, and participants were selected only from first-grade classrooms in the participating schools. One slight change in implementation was made by one of the physicians. The bilingual schools randomly selected by the researchers were located in a place difficult for the zone physician to access within the timeframe of the study. Therefore, five different bilingual schools in the same province were selected.

The sampling procedure might have created a slightly biased sample because students from poor families or students with hearing loss are probably less likely to attend school on any given day. However, the sample sizes in the study were large enough to ensure enough children from low-income families and enough children with hearing loss to draw conclusions about the accuracy and effectiveness of the teacher-administered hearing screening questionnaire.

As described in more detail below, results from Phase 1 showed that the questionnaire was not effective in identifying children with hearing problems. However, staff in the Vice

President's Office had invested time and effort in developing the questionnaire, and they wanted to see if it could be improved. They hoped that improving the questionnaire and the procedures for training, referral and follow-up would lead to better outcomes. Because buy-in is critical for effective change, it was determined that using the results from Phase 1 to improve the questionnaire as much as possible, and then evaluating the outcomes for the revised questionnaire and procedures during the second phase of the study, would provide valuable data to the government when making policy decisions related to hearing screening procedures for school-aged children.

Focus groups. For Phase 1, six focus groups were held at three different locations with teachers and parents who participated in the 2012 screening. Efforts were made to include participants from rural and urban settings, and 33 schools were represented. A subcontract was executed with Fundación DHEx Vivir la Sordera, an Ecuadorian business, to assist in the organisation of the focus groups and to transcribe the audio recordings from each session. The focus groups were conducted by Dr Eduardo Ortiz and were held in neutral locations. In Quito, the groups met at Fundación DHEx facilities, and in Esmeraldas and Loja the groups met in hotel conference rooms. Each group met for approximately two hours. Participants were reimbursed for their travel expenses. Focus groups conducted during Phase 2 were similar to Phase 1, except that they were conducted with teachers and parents who had participated in Phase 1. During Phase 2, focus groups were held at two locations instead of three, as originally planned. This change was made because it was more difficult within Ecuador to obtain the necessary paperwork to organise focus groups, which delayed the process.

Cost data. Cost data were collected as a part of the evaluation study to address both administrative and family cost considerations for children who were screened, as well as those who failed the hearing screening and received additional diagnostic testing. A questionnaire-based screening, such as the one used in this study, is most likely to identify children with bilateral hearing losses. Results from the audiometric testing were used to evaluate the accuracy and effectiveness of the teacher-administered questionnaire. However, screening with audiometers was not implemented as it would have been had audiometry been used as the primary tool in a national screening programme. For example, if audiometry were to be used in a national screening programme, it would likely be a two- or three-stage screening process in order to reduce the number of false positives in the diagnostic evaluation process.

Costs associated with the teacher-administered hearing screening questionnaire included those related to producing and distributing the materials, training, administering the questionnaire and managing follow-up. Costs associated with the audiometric testing included training and screening time, as well as travel costs for audiologists to get to schools. Data about the costs of conducting hearing screening were collected from teacher surveys, focus groups and interviews with staff in SETEDIS. Costs to families for diagnosis and follow-up included family time spent on travel and appointments, lost wages or other family income, costs of transportation to clinics, lodging and meal costs, and other cost data identified during the focus groups.

7. Impact analysis and results of the key evaluation questions

This study was done to evaluate the accuracy and effectiveness of a newly implemented procedure to screen the hearing of school-aged children using a teacher-administered questionnaire, and to provide data about the selected screening approach for the formation of policy for national screening practices. This was not an impact evaluation to study changes attributed to a particular intervention, and it was not designed to provide data about how to implement an alternative screening.

The study was completed in two phases. Hearing screening results for Phase 1 represent findings from the Amazon and highland regions, and results for Phase 2 represent findings from the coastal region. A survey was conducted to obtain feedback about the teachers' experience with completing the questionnaire screening. Focus groups were conducted to get insights from parents and teachers about the hearing screening process based on the teacher-administered questionnaire. Cost data related to the hearing screening process were obtained. Findings for each of the five planned evaluation questions are reported below.

7.1 How effective is Ecuador's teacher-administered hearing screening questionnaire programme as evidenced by the percentage of children in each of the four cells? (see Figure 1)

7.1.1 Phase 1: Audiometry compared with questionnaire. The main goal of the evaluation study was to determine if the questionnaire-based hearing screening procedures identified the same children with hearing loss as were identified by the 'gold standard' audiometric screening method. As such, this 'noninferiority' study (Durkalski *et al.* 2003; Piaggio *et al*. 2006) sought to determine whether the teacher-administered hearing screening questionnaire was better or worse than the audiometric screening.

Results of screening with an audiometer were used as the reference standard to determine the accuracy of the questionnaire-based hearing screening procedures currently being used. Differences between the two procedures were evaluated using the McNemar's test for assessing differences between two correlated proportions. Although the McNemar test appears to be similar to a test of categorical association, such as is done by a 2 x 2 chi-square test or a 2 x 2 Fisher exact probability test, it measures something quite different. Tests of association examine the relationship that exists among the *cells* of the table. As shown in Figure 1, the McNemar test examines the difference between the proportions that derive from the marginal sums of the table: $p_A = (a + b) / N$ and $p_B = (a + c) / N$. The question the McNemar test addresses is: are there statistically significant differences between these two proportions, p_A and p_B? The answer must account for the fact that the two proportions are not independent because the data for Cell '*a*' used to calculate both proportions were collected for the same children (see http://vassarstats.net/propcorr.html for a more complete explanation).

Figure 1 Elements used in McNemar's test for assessing differences between two correlated proportions

		Results of standard audiometric screening conducted by audiologists: FAIL	PASS	Total
Results of teacher-administered questionnaire-based hearing screening	FAIL	a	b	P_A = a + b
	PASS	c	d	c + d
	Total	P_B = a + c	b + d	a + b + c + d

The sample for Phase 1 of this evaluation study consisted of 3,197 first-grade students from 82 schools in the following 17 provinces: Pichincha, Orellana, Azuay, Carchi, Imbabura, Cañar, Chimborazo, Tungurahua, Morona Santiago, Cotopaxi, Pastaza, Sucumbíos, Bolívar, Zamora Chinchipe, Napo and Loja. A total of 178 teachers completed the teacher questionnaire. Of the 3,197 students, 3,022 students were assessed with both the teacher questionnaire and audiometry. Figure 2 shows the distribution of numbers for McNemar's test as well as the percentages of children passing and failing the hearing screening questionnaire and the audiometric test. The unsigned difference, $P_B - P_A$, is –0.016. The odds ratio of discordant (i.e. disagreeing) cells with the larger divided by the smaller (175 / 125) is 1.4. The McNemar's test for either a one- or two-tailed test is statistically significant at $p < .000001$. This indicates that the two proportions, P_A and P_B, are statistically significantly different, meaning that the proportion of fails from audiometry and the proportion of fails from the teacher questionnaire are statistically significantly different. In other words, the statistically significant difference suggests the teacher questionnaire does not adequately reflect results from the gold standard method of audiometry.

Figure 2 Phase 1 percentages of children passing and failing each hearing screening method

Phase 1 comparison of teacher-administered hearing screening questionnaire (v.1) and pure tone audiometry

		Pure tone audiometry: Bilateral Fail	Pure tone audiometry: Pass	Total
Teacher-administered hearing screening questionnaire, version 1	Fail	0.7% (*n* = 22)	5.8% (*n* = 175)	6.5% P_A = .0651 (*n* = 197)
	Pass	4.1% (*n* = 125)	89.3% (*n* = 2,700)	93.5% (*n* = 2,825)
	Total	4.9% (*n* = 147) P_B = .0486	95.1% (*n* = 2,875)	100% (*n* = 3,022)

It is not surprising that the results are statistically significantly different on the two methods, even though 90.0 per cent (89.3% + 0.7%) of the children had the same results on both tests because hearing loss is a relatively low-incidence condition. However, it is very concerning that 89 per cent of the children who failed the hearing screening questionnaire passed the audiometry (175 ÷ 197 = 88.8%); and 85 per cent of those who failed the audiometry passed the hearing screening questionnaire (125 ÷ 147 = 85.0%). Audiometry is widely recognised as the gold standard for hearing screening (Bamford *et al.* 2007; AAA 2011; British Society of Audiology 2011); thus the 125 children who passed the teacher questionnaire likely need further assessment because they failed the audiometry (false negatives). In essence, the teacher questionnaire is missing many children who are likely to have hearing loss that will interfere with their language and academic development. Additionally, 175 children who failed the teacher-administered questionnaire passed the audiometry (false positives). These children, their families and the clinics that provide further testing for hearing loss are expending resources for follow-up testing of these children even though they are not likely to need it.

7.1.2 Phase 2: Audiometry compared with teacher questionnaire.

The sample for Phase 2 of this evaluation study consisted of 1,750 first-grade students from 37 schools in seven provinces: Esmeraldas, Santo Domingo de los Tsáchilas, El Oro, Los Ríos, Guayas, Santa Elena and Manabí. Of the 1,750 students, 1,594 students were assessed with both the teacher questionnaire and audiometry.

Figure 3: Phase 2 results of hearing screening using teacher-administered questionnaires and audiometry

		Pure tone audiometry		
		Bilateral Fail	Pass	Total
Teacher-administered hearing screening questionnaire, version 2	Fail	2.9% (n = 47)	7.3% (n = 117)	10.3% (n = 164)
	Pass	17.4% (n = 277)	72.3% (n = 1,153)	89.7% (n = 1,430)
	Total	20.3% (n = 324)	79.7% (n = 1,270)	100% (n = 1,594)

When comparing the calculated results from the teacher-administered questionnaire (based on how teachers marked items 1 through 10 that described child behaviour) and bilateral fail rates (based on how the people administering the audiometry marked each frequency), the results shown in Figure 3 indicate a fail rate of 10 per cent for the teacher-administered questionnaire and a fail rate of 20 per cent for audiometry for children who had both sets of data. However, only 3 per cent of the total number of children screened failed both the teacher questionnaire and audiometry. McNemar's test shows that the proportion of children who failed audiometry (324 of 1,594), when compared to the proportion of children who failed the teacher questionnaire (164 of 1,594), was statistically significantly different ($p < .000001$).

Results from Phase 2 revealed a slight improvement in agreement between the two methods with the revised questionnaire. Specifically, 71 per cent of the children who failed the hearing screening questionnaire passed the audiometry (117 ÷ 164 = 71.3%); whereas this figure was 89 per cent during Phase 1 (see Figure 3). The percentage of children who failed audiometry but passed the hearing screening questionnaire (277 ÷ 324 = 85.4%) was the same during Phase 1 and Phase 2. Thus, there were fewer false positives in Phase 2.

Some previous studies that have evaluated the accuracy and effectiveness of questionnaires as a screening tool have reported sensitivity and specificity figures (see e.g. Li, Driscoll and Culbert 2009; Samelli, Rabelo and Chaparin 2011). In all of these studies, the terms 'sensitivity' and 'specificity' are being used because data are not available about the final hearing status of all children. The same is true in this study. So, even though it is very useful to report the agreement between the teacher-administered hearing screening questionnaire and the results of the audiometer (widely recognised as the gold standard of hearing screening), it is not appropriate to report sensitivity and specificity in the absence of diagnostic audiological data for all children in the study.

7.2 What percentages of children who fail the teacher-administered hearing screening questionnaire complete a diagnostic evaluation at a local health facility within three months?

7.2.1 Diagnostic follow-up for children failing 2012 questionnaire screening. The Office of the Vice President provided Utah State University with screening and follow-up data from the 2012 implementation of the Tamizaje Auditivo Escolar programme. The results represented the initial roll-out of the screening programme and the first-time teachers were asked to complete the hearing screening for children in their classrooms. For some schools, outcomes were available for children who failed the school screening and received further testing, but the timeframe (i.e. whether further testing occurred within the recommended three-month period) was not included. Follow-up testing is an essential aspect of hearing screening, and the lack of follow-up data in this study revealed the need to address aspects of the referral process for children who fail the screening.

Children in the first through third grades were targeted for hearing screening, and 428,072 children in 3,852 schools, representing all 24 provinces, were screened. Table 4 shows the number of schools and the number of questionnaires that were sent, the number and percentage of students screened (based on the number of questionnaires returned to the Office of the Vice President), the number and percentage of students referred (based on the questionnaires returned), the number of children for whom the Vice Presidency received follow-up information, and the number of children documented as being diagnosed with hearing loss.

As can be seen in the data from Table 4:

1. Many schools returned more hearing screening questionnaires than they were sent. For example, school Club Arabe Ecuatoriano in Pichincha province was sent 260 questionnaires, but returned 371. Some of this discrepancy might be because some schools screened children outside the targeted grades. For example, in Pichincha,

some children who were referred for additional testing were in the sixth grade.

2. Some schools returned questionnaires even though the Vice Presidency did not distribute questionnaires to those schools. For example, Jim Irwin, Jardin Joaquin M. Soto, Pedro Jose Arteta and Jardin Fiscal Isaac Newton schools in Pichincha were not on the list of schools included in the first year of implementation of Tamizaje Auditivo Escolar, but were included in the summary spreadsheet for Pichincha.
3. No follow-up data were available for 13 provinces (54 per cent), as shown by the rows with no data in Table 4. The follow-up for the other 11 provinces was incomplete. It is not known if the schools for which there is no data did not submit information about the screening results, or did not identify any children who needed to be referred.

Table 4 Hearing screening questionnaire 2012: sent or returned to schools; children referred or diagnosed with hearing loss

PROVINCE	SUMMARY DATA PROVIDED BY ECUADOR'S VICE PRESIDENT'S OFFICE						SUMMARY CALCULATED FROM STUDENT-LEVEL DATA PROVIDED BY VICE PRESIDENT'S OFFICE		
	NUMBER SENT		NUMBER RETURNED						
	Number of schools	Number of questionnaires	Number students screened	Per cent screened	Number students referred	Per cent referred	Have names of referred	Number with follow-up information	Number with hearing loss
Azuay	234	30,817	25,110	81%	**685**	3%	685 students from 126 schools	110	19
Bolívar	105	6,580	6,160	94%	218	4%			
Cañar	120	13,706	12,125	88%	**312**	3%	**Spanish:** 313 from 66 schools **Bilingual:** 30 from 10 schools	31 0	15
Carchi	50	7,100	6,796	96%	238	4%			
Chimborazo	157	18,935	17,639	93%	**520**	3%	229 students from 25 schools	215	34
Cotopaxi	70	18,609	13,370	72%	372	3%			
El Oro	148	28,446	22,241	78%	1,481	7%			
Esmeraldas	82	23,881	18,787	79%	**667**	4%	652 students from 61 schools	6	3
Galápagos	47	2020	1,932	96%	69	4%			
Guayas	294	75,710	59,835	79%	1,749	3%			
Imbabura	472	30,681	17,426	57%	380	2%			
Loja	64	11,987	11,339	95%	**445**	4%	49 students from 16 schools	37	9
Los Ríos	101	14,821	12,371	83%	365	3%			
Manabí	200	18,600	17,922	96%	622	3%			
Morona Santiago	97	7,881	6,324	80%	**290**	5%	**Spanish**: 87 from 14 schools **Bilingual**: 61 from 18 schools	8 0	1
Napo	165	8,842	6,965	79%	**392**	6%	392 students from 58 schools	78	32
Orellana	117	11,069	10,156	92%	**518**	5%	539 students from 84 schools	140	25

PROVINCE	SUMMARY DATA PROVIDED BY ECUADOR'S VICE PRESIDENT'S OFFICE						SUMMARY CALCULATED FROM STUDENT-LEVEL DATA PROVIDED BY VICE PRESIDENT'S OFFICE		
	NUMBER SENT		NUMBER RETURNED						
	Number of schools	Number of questionnaires	Number students screened	Per cent screened	Number students referred	Per cent referred	Have names of referred	Number with follow-up information	Number with hearing loss
Pastaza	206	8,166	6,960	85%	**415**	6%	**Spanish**: 83 from 16 schools **Bilingual**: 13 from 2 schools	76 13	3 0
Pichincha*	213	85,974	74,391	87%	**2,047**	3%	2,047 students from 203 schools	32	4
Santa Elena	257	29,863	28,083	94%	**685**	2%			
Santo Domingo de los Tsáchilas	99	22,641	15,223	67%	**1,058**	7%			
Sucumbíos	72	9,877	9,340	95%	**346**	4%			
Tunguarahua	96	20,805	18,625	90%	**685**	4%	165 students from 22 schools	165	10
Zamora Chinchipe	386	10,708	8,952	82%	**502**	6%			
TOTAL	**3,852**	**517,719**	**428,072**	**83%**	**15,061**	**3.5%**	**5,345 students from 721 schools**	**911**	**155**

* Four schools that were not on the original list returned questionnaires. The total number of students in the blue column does not include these students. However, students from these four schools are included in the students screened and referred columns.

Based on the data in Table 4, 15,061 children (3.5 per cent) were documented as having failed the hearing screening questionnaire and were referred for further testing. From the 911 children for whom follow-up testing data are available, 155 were identified with hearing loss. Therefore, the documented incidence of hearing loss was 0.36 per 1,000 children (155 ÷ 428,072 = 0.00036). Table 5 shows the percentage of children who completed different stages of the referral and diagnostic process. This information is represented differently depending on whether the denominator is the data from all 24 provinces or just the data from the 11 provinces that submitted data to the central database maintained by the Vice President's Office.

Table 5 Percentage of children completing referral and diagnostic process

	Based on all 24 provinces	Based on 11 provinces that submitted data
Number of children referred from hearing screening questionnaire	15,051	6,976
Percentage of referred children for whom names were sent to the central database	35.5%	76.7%
Percentage of referred children for whom some diagnostic information exists	6.1%	13.1%
Percentage of referred children diagnosed with hearing loss	1.0%	2.2%

As can be seen in Table 5, even if we consider only the data from the 11 provinces that submitted data to the central database (which is the best-case scenario), diagnostic information of any kind was received from only 13.1 per cent of the children who were referred from the results of the hearing screening questionnaire in 2012. Considering the data from all 24 provinces, we do not know what happened with 93.9 per cent of the referred children. Only 1.0 per cent of the referred children were diagnosed with hearing loss.

7.2.2 Diagnostic follow-up for children failing Phase 2 screening. Diagnostic data were not available for children who failed the screening during Phase 1 of the study. National elections immediately following the data collection period caused uncertainty with respect to the election outcome, and data were not collected by the Vice President's Office.

Better diagnostic data were collected for Phase 2 of the study. There was documentation of the completion of an audiological diagnostic evaluation for 322 (56 per cent) of the 562 children who were referred for an audiological diagnostic evaluation during Phase 2 because they failed the teacher-administered questionnaire and/or audiometry. Twenty-seven of those children were diagnosed with hearing loss as shown in Figure 4. Twenty-four of these 27 children (89 per cent) failed audiometry, but only 6 of the 27 failed the teacher-administered hearing screening questionnaire (22 per cent).

Figure 4 Hearing screening results for children identified with hearing loss during Phase 2 screening

		Pure tone audiometry		
		Fail	Pass	Total
Teacher-administered hearing screening questionnaire	Fail	**5**	**1**	**6**
	Pass	**19**	**2**	**21**
	Total	**24**	**3**	**27**

These results are further evidence that the teacher-administered hearing screening questionnaire will miss many children who have hearing loss. As discussed below, it is noteworthy that the percentage of children identified with permanent hearing loss was twice as high in bilingual schools compared to Spanish schools, and three times as high in rural areas compared to urban areas.

7.3 How satisfied are teachers and parents with the hearing screening and referral procedures being used in Ecuadorian schools?

7.3.1 Results from anonymous teacher surveys. In Phase 1, a total of 178 teachers returned surveys, with at least 1 and as many as 10 teachers from each school responding. In Phase 2, a total of 75 teachers returned surveys, with between 1 and 3 teachers from each school responding. Combined, about 86 per cent of the teachers reported that they taught in Spanish classrooms. In Phase 1, the average class size was 28 students with a minimum of 1 and a maximum of 45. In Phase 2, the average class size was 32 students with a minimum of 20 and a maximum of 43. Combined, teachers had completed an average of 16.9 years of school teaching, with a minimum of 3 and a maximum of 32, although 14 per cent of teachers did not respond to this question. While some teachers were in their first year of teaching, others had more than 40 years of experience, with the average number of years of teaching being 17.8. Some were new to the school community, while others had lived in the school community their entire life, or 63 years. The average number of years spent in the school community was over 31 years (range 3 to 60), though more than 20 per cent of the teachers did not respond to this question.

Teachers reported that, on average, it took just over 5 minutes to complete the questionnaire for each child, with a range of 1 to 20 minutes. In Phase 1, 121 (68 per cent) of the 178 teachers had conducted the Tamizaje Auditivo Escolar screening in 2012, while 51 teachers reported that it was the first time they had screened children for hearing loss. In Phase 2, 25 (33 per cent) teachers had conducted the Tamizaje Escolar Auditivo screening previously, while 42 teachers reported that it was the first time they had screened children for hearing loss.

The charts in Table 6 display teachers' responses to specific questions. Overwhelmingly, teachers thought the Tamizaje Auditivo Escolar programme was important, with over 98 per cent of respondents indicating it was very important. However, teachers were less certain about the accuracy of the screening results, with only 38 per cent in Phase 1 and

60 per cent in Phase 2 reporting that they believed the results were very accurate, though over 90 per cent responded on the positive side of the 4-point scale. Additionally, almost 93 per cent responded positively with regard to satisfaction with outcomes.

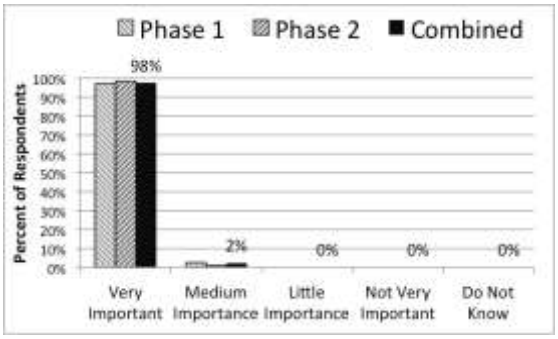
Only 28 per cent of the teachers reported feeling very well trained to administer the questionnaire, though nearly 79 per cent responded in the positive direction for this question. Nearly 90 per cent felt satisfied or very satisfied with the information provided to them about the hearing screening, and over 90 per cent were comfortable with what to do with the screening results (i.e. notify parents if a hearing concern was identified).

In Phase 1, teachers' responses to open-ended questions indicated that they felt rushed, given the study requirements of completing the questionnaire on the same day that the audiometric hearing screening was being completed. This may have affected their responses to these questions. Also, given the number of teachers who had not previously participated in hearing screening, the short training teachers received on the day screening was conducted at the school may have been insufficient to help them understand the purpose and process of administering the questionnaire.

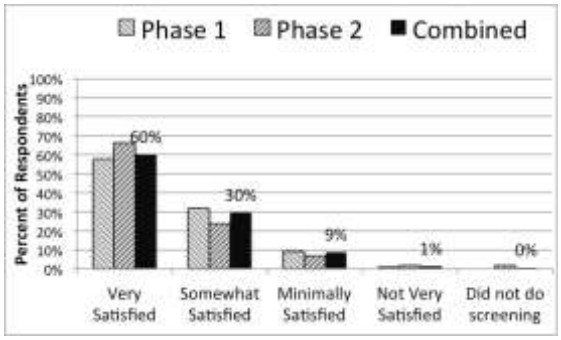
In Phase 2, teachers' responses to the open-ended questions suggested that 23 per cent of teachers paid more attention to children with hearing loss as a result of participating in the Tamizaje Auditivo Escolar programme. Another 11 per cent mentioned talking louder and more clearly, and 8 per cent reported trying to learn more about how to teach children with hearing loss. When asked how to improve the programme, 18 per cent of teachers requested more professional help in working with children with hearing loss, and 17 per cent said schools should be more involved in helping the children. The next most frequent responses (8 per cent or fewer) included involving families more, improving screening methods and helping teachers learn how to teach children with hearing loss. It is important to note that 25 per cent of respondents indicated that they would change nothing, and 18 per cent said that the programme should be continued.

Table 6 Responses to teacher survey questions

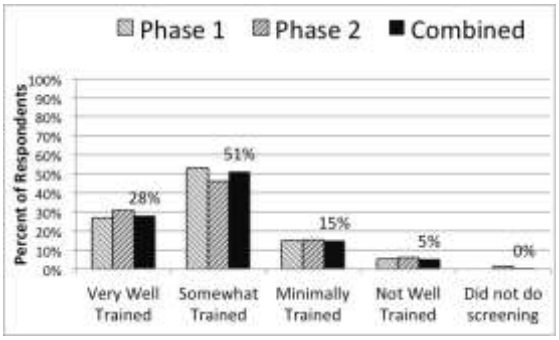
How important has the hearing screening programme been for you as a teacher?



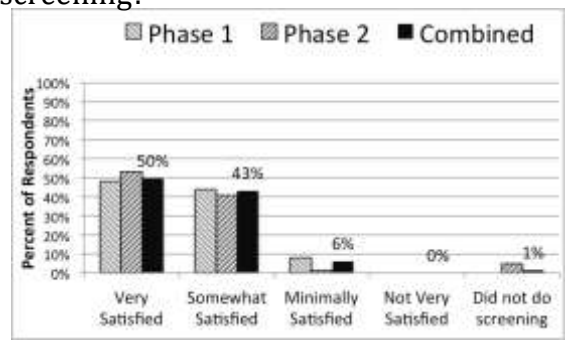
How well trained did you feel for the hearing screening?



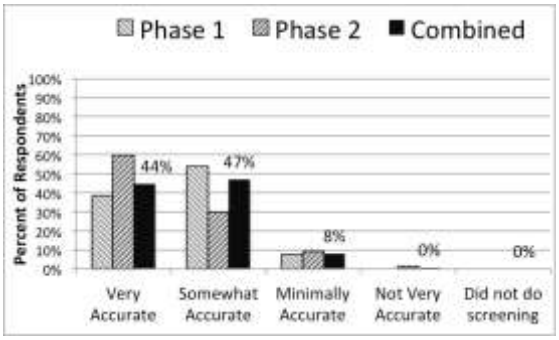
How accurate do you think the school hearing screening results are?



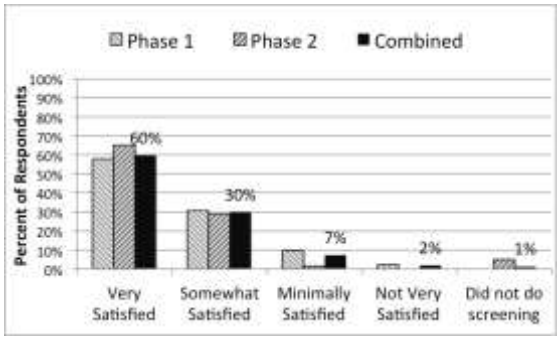
How satisfied are you with the information you were given about the hearing screening?



How satisfied are you as a teacher with the outcomes obtained from the hearing screening results?



How satisfied are you with the information you were given about what to do with the results after the hearing screening?



7.3.2 Results from focus groups. To obtain more information about the Tamizaje Auditivo Escolar programme from the perspective of parents and teachers, focus groups were conducted with people from both urban and rural settings. Phase 1 focus groups included people from 33 schools (32 parents and 32 teachers) where children were screened in the initial roll-out of Tamizaje Auditivo Escolar during 2012. Focus groups done during Phase 2 included people from 15 schools (29 parents and 17 teachers) where children were screened in Phase 1 of the evaluation study. The following questions were posed in each focus group:

1. How was your experience with the school hearing screening programme?
2. How effective do you think the programme has been in determining hearing results?
3. How did follow-up testing go for children who did not pass the screening in your class (teacher groups only)?
4. What did you like or dislike about the programme and its process?
5. Are you aware of any unintended outcomes from the screening?
6. How valuable do think the screening is?
7. What costs are associated with the screening for you and/or your family?

A qualitative inductive analysis was completed and common themes were identified from the responses to questions posed to the people in each group. As summarised in Table 7, there were eight themes that emerged from the focus groups conducted during Phase 1. Some of these are further discussed below.

Table 7 Phase 1 focus group themes

Theme	Frequency of response (%)	
	Parents	Teachers
1. Communication problems among stakeholders	62%	90%
2. Inconsistent screening procedures	N/A	31%
3. Problems with access to health services	66%	38%
4. Additional cost to families	72%	38%
5. Lack of teacher training	24%	93%
6. Lack of parent participation	N/A	55%
7. Teacher suggested changes to improve process	N/A	90%
8. Support for hearing screening	69%	31%

Communication problems among stakeholders. Parents and teachers reported that they were unclear about the process for the Tamizaje Auditivo Escolar programme and felt that school principals and healthcare providers were also unclear about the process, procedures and next steps when a child did not pass the screening. Many parents (62 per cent) did not know until a few days before the focus group meeting that their child had failed the school hearing screening. For example, one parent said:

> *'I don't remember if they gave a form to my child. I also just learned yesterday morning that my child might have hearing difficulties.'*

According to some focus group participants, there were cases where health centres were not aware about the programme details and procedures. Furthermore, the teachers (90 per cent) were confused about the process; they reported that they had waited for results and outcomes to come from the Vice President's Office, but these never arrived.

> *'(Hearing screening results) went to Vice Presidency Office and they sent them to the health centres. These got lost somewhere, because from there I don't know, they didn't come back to me…. They didn't tell me anything.'*

Inconsistent screening procedures. During the national roll-out of Tamizaje Auditivo Escolar, screening was intended for children of ages 6 to 9 in each school; however, schools apparently made decisions differently about whom to include for the screenings completed in 2012. Some schools screened the whole school, and some schools selected a subsample such as: (*a*) only children suspected of having a hearing problem; (*b*) only children from one classroom; (*c*) only children from one grade. In addition, some teachers worked with their students individually, and other teachers worked with their students as a group.

> *'In a school having 512 students we did hearing screenings for only 35… there were not forms, we chose a representative sample.'*

Problems accessing healthcare services. There was a consistent trend among both parents and teachers about difficulties with accessing health services. For example, 66 per cent of the parents complained about the time it took to access public health services for their children and the process for obtaining those services. Also, many parents complained about the lack of hearing specialists and equipment at the health centres.

> *'The school called to all the parents so we could go together (to the health centre). It was supposed we already had scheduled appointments (with the doctor)… we got there and they told us the health centre didn't have any scheduled appointment for us because (a) there was not a hearing specialist for the children…; (b) they didn't have the specialized equipment…. All the parents were called to come back 15 days later. Then I didn't take to my child there…'*

Additional costs to families. Parents reported that they incurred expenses for the time they spent accessing follow-up testing (e.g. transportation, meals, medicines, lab exams and sometimes even private doctors). Also, there were cases where parents could not afford the costs of travel or private services, so they didn't take their children to the health centre. There were also cases where teachers had to pay from their own pockets. In addition, there was at least one case where a parent lost his job because going to follow-up appointments interfered with his employment.

> *'The major problem is access to the specialist and the time it requires. Many things get complicated…. that day my wife had to replace me in my work and there was nobody who can pick up my girls from the bus.'*

'From my place to the hospital takes around 1½ to 2 hours traveling. It required three days when I should have been working—time and money we had to spend and then our child couldn't be examined because the doctor wasn't there.'

In addition, parents and teachers reported on lack of teacher training, lack of parent participation, and support for school hearing screening activities. Also, teachers shared many suggestions for changes that could be made to improve the school hearing screening programme process (e.g. including hearing experts for activities at the school; doing screening annually at the beginning of the school year; screening all the students).

The seven themes that emerged from the focus groups conducted during Phase 2 are summarised in Table 8. Some of them are described below.

Table 8 Phase 2 focus group themes

Theme	Frequency of response (%)	
	Parent	Teachers
1. Communication problems among stakeholders	72%	N/A
2. Problems with access to health services	62%	N/A
3. Lack of teacher training	N/A	71%
4. Parent stress and worry	59%	N/A
5. Lack of project follow-ups (teacher expectations)	N/A	82%
6. Support for hearing screening	97%	53%
7. Teachers' concerns about programme process	N/A	71%

Communication problems among stakeholders. Parents and teachers reported that they were unclear about the process and felt that healthcare providers were also unclear about the procedures when a child did not pass the screening. Many parents (72 per cent) did not know exactly where to go and/or what to do after learning that their child had failed the teacher-administered hearing screening.

'I didn't know anything, the teacher told me nothing. The teacher gave me a note and told me to go to the health center. My child didn't want to go for a hearing screening and there was not any available space for that date, so I couldn't go. In other words, I didn't know who to talk with, and I didn't know where to go.'

Problems with access to health services. There was a consistent trend among parents about difficulties with accessing health services. For example, 62 per cent of the parents complained about problems getting access to public health services for their children and the process for obtaining those services. Parents shared the negative experiences they had had in the past and expressed distrust in the healthcare system:

'They gave me a note to go to the health centre. I went but they told me the equipment was not working. Then I couldn't do anything….

They gave me some papers to go to the health centre… they gave me another appointment and I did go, but they told me the doctor was sick and

I couldn't do anything. The doctor didn't come back and the healthcare centre closed for good, then I didn't go anymore.'

Lack of teacher training. Many teachers (71 per cent) reported that there was inadequate school hearing screening training or programme support. Many teachers said they did not know how to handle some questions from the hearing screening questionnaire. They considered some of the children's answers unreliable.

'I think they should have trained the teachers better. We took it kind of lightly. They should have given us more time so we could talk with the parents. Then it would have been a more successful school hearing screening.'

Parent stress and worries. Parents (59 per cent) commented on their experience of stress related to the school hearing screening process. Parents were worried about their children's hearing results, and sometimes they looked for additional professional opinions that cost them extra money, time and family resources.

'I worried a lot and didn't know what to do. The school is telling me my child has a hearing problem, the specialist is telling me the child is fine. I still have doubts. Do I have to get a third opinion?… We are spending time, resources…'

Teachers reported on the lack of follow-up activities (82 per cent) for those who failed hearing screening and expressed concerns about the school hearing screening process (71 per cent). Some of the teachers' concerns included having sufficient time to do the screening, having trained professionals, and using suitable places for the school screening activities. However, parents (97 per cent) were very supportive and valued the school hearing screening programme.

7.4 Are the answers to any of the previous questions different for families living in different regions (highlands, coastal or Amazon), different socio-economic circumstances, or urban versus rural locations?

For Phase 1 of the study, the percentage of children who failed both audiometry and the teacher-administered hearing screening questionnaire was nearly the same for all children (bilingual children and Spanish-speaking children). In Phase 2, the fail rate of bilingual children was substantially greater than it was for Spanish children. Based on the diagnostic test results from Phase 2 of the study, there was also a greater prevalence of hearing loss among bilingual children.

There were minimal differences noted between urban and rural schools in Phase 1. However, in Phase 2, children in urban schools were substantially more likely to fail audiometry. However, a substantially greater percentage of children in urban schools who failed audiometry passed the teacher-administered questionnaire. Additionally, in Phase 1, there was little difference between Amazon and highland schools.

For children who received diagnostic testing, the percentage of children with hearing loss was greater for those children in bilingual classrooms (see Figure 5) and rural classrooms (see Figure 6). A large percentage of bilingual schools are located in rural areas as these schools serve mostly Quechan children. Row percentages indicate

differences between groups. Therefore, even though sample sizes are small, hearing loss was more likely to be present in bilingual or rural schools.

Because data about the socio-economic status of children were not available from the Vice President's Office, analyses could not be done to determine if the teacher-administered hearing screening questionnaire was differentially effective for children in different socio-economic circumstances.

Figure 5 Phase 2 percentages of children with normal hearing and hearing loss based on language spoken in the classroom

		Language		
		Spanish	Bilingual	Total
Diagnosis	Normal	**91.6%** (*n* = 272)	**84.6%** (*n* = 11)	**91.3%** (*n* = 283)
	Hearing loss	**8.4%** (*n* = 25)	**15.4%** (*n* = 2)	**8.7%** (*n* = 27)
	Total	**95.8%** (*n* = 297)	**4.2%** (*n* = 13)	(*n* = 310)

Figure 6 Phase 2 percentages of children with normal hearing and hearing loss based on urban or rural location

		Community Size		
		Urban	Rural	Total
Diagnosis	Normal	**92.7%** (*n* = 278)	**77.3%** (*n* = 17)	**91.6%** (*n* = 295)
	Hearing loss	**7.3%** (*n* = 22)	**22.7%** (*n* = 5)	**8.4%** (*n* = 27)
	Total	**93.2%** (*n* = 300)	**6.8%** (*n* = 22)	(*n* = 322)

7.5 What are the costs associated with the hearing screening and referral processes? In particular, what are the costs to families and the Ecuadorian health system associated with referring children for diagnosis when children are incorrectly identified with hearing loss?

7.5.1 Cost-effectiveness analysis. Cost data were collected to address both administrative and family cost considerations for children who were screened, as well as those who failed the hearing screening and were referred for and received additional diagnostic testing.

The plan, as described in the approved Research Protocol (pp.9–10), was to collect cost data for the following:

- School-based teacher-administered hearing screening questionnaire including wages and time for training, administration and follow-up; materials; and lost instructional time.

- Testing with audiometry including wages and time for training, administration, follow-up, travel costs; and materials.

- Additional time and materials required for administrative functions related to school-based hearing screening, including scheduling, informing families about children's hearing loss, follow-up, managing paperwork, copying forms, mailing data and so on.
- Cost of diagnostic assessment for hearing loss at local health clinics including wages and time for scheduling, assessment and follow-up; equipment, materials and maintenance costs; and other costs related to diagnostic assessment that are identified during site-based observations and interviews.

Cost data was collected using information from teacher surveys, teacher and parent focus groups, zone physicians and audiologists, and from Ms Edith Luzuriaga and others associated with the hearing screening project at the ministry offices. However, our Ecuadorian partners were not able to provide the costs of diagnosis, as those costs are part of their public health system, and they were not able to separate out the costs we requested. Therefore, we focused on the first four bullets included in the approved Research Protocol.

Costs to families were calculated for diagnosis and follow-up, including family time spent on travel and appointments, lost wages or other family income, transportation costs to clinics, lodging and meal costs, childcare, and other cost data identified during focus groups that were deemed relevant for determining costs associated with incorrectly identifying children with hearing loss.

7.5.2 Teacher-administered hearing screening questionnaire. Costs associated with the teacher-administered hearing screening questionnaire included those related to producing the materials, distribution, training, administering the questionnaire and managing follow-up. Data about the costs of conducting hearing screening were collected from teacher surveys, focus groups and interviews with staff in SETEDIS. Costs to families for diagnosis and follow-up included family time spent on travel and appointments, lost wages or other family income, costs of transportation to clinics, lodging and meal costs and other cost data identified during the focus groups.

Ecuadorian teacher salaries range from $527 to $1,676 per month, with an average of $1,102 per month or $55 per day. Teacher training for the questionnaire required approximately one hour. Based on averages reported in teacher questionnaires, teachers spent 15 minutes per student to prepare materials with names, complete the Phase 2 version of the questionnaire-based hearing screening, record results, and submit the paperwork to an administrator. Hence, a 20-student classroom (about the average for the classrooms from which data were collected) required 300 minutes, or 5 hours, plus 1 hour of training.

Table 9 School-based costs related to teacher-administered questionnaire screening

Description of costs	Time	Expense
Training time	1 hour	
Screening time for 20 students (paperwork, screening, recording results) @ 15 minutes each	5 hours	
Contacting parents if 12% failure rate (2.4 students) @ 20 mins each	0.8 hour	
TOTAL per classroom (presume 7 hours is 1 school day)	6.8 hrs	$55 per day
TOTAL teacher costs per **screened** child ($55 / 20)		$2.75/screened child
TOTAL teacher costs per **referred** child (total cost / children referred or $55 / 2.4; 235 children should have been referred through teacher screener)		$22.92/referred child
TOTAL teacher costs per **diagnosed** child if presumed that 3 of 235 were diagnosed with hearing loss (Cost per screened child x 1,774) / 6 with hearing loss)		$813/child identified with hearing loss

During Phase 2 focus groups, 29 families were interviewed. Of those, 22 reported visiting a clinic for diagnosis of a child's hearing loss; 21 of these 22 provided usable data. Sixteen families went to clinics once, while 6 families (27 per cent) went twice. Data are summarised in Table 10.

The following costs can be calculated for families whose children were referred during the screening process, using the actual costs shown in Tables 10 and 11. Additional attribution of costs to families due to time lost has not been made. Only direct expenses are used in the following calculations (see Table 11).

Taken together, the cost of the teacher-administered hearing screening questionnaires and communicating results at $2.75 per child for 1,774 children during Phase 2 of the study was $4,878 ($2.75 x 1,774 = $4,878). This does not include the cost of doing the diagnostic audiological evaluations. The average cost to families participating in the diagnostic audiological evaluations ($3.23 per child) was an additional $5,730 ($3.23 x 1,774 = $5,730). The total cost was $10,605—a little less than the average teacher's salary for one year. Given that six children were identified with permanent hearing loss based on the results of the teacher-administered hearing screening questionnaire, the cost per child identified with hearing loss was $1,768, and the average cost of just the questionnaire-based screening programme was $2.75 per child.

Table 10 Average cost per family related to diagnostic evaluations

Item	Visit 1 (22 families)	Visit 2 (6 families)
Distance to clinic	Average 7.4 km, range 1–20 km	Average 6 km with range 1–15 km
People accompanying child	Mother (9), father (3), both parents (1) or sibling (1)	Mother (3), both parents (1)
Mode of travel Taxi Bus Walk Both walk and taxi Car	 6 6 4 1 1	 2 2 1 0 1
Travel time	Average 0.77 hrs or 46 mins Range 5 mins to 3 hrs	Average 0.78 hrs or 47 mins Range 5 mins to 2 hrs
Time gone from home	Average 7.77 hours Range 2 hrs to 2 days 8 hrs	Average 3.2 hrs Range 2–6 hrs
Did other things while travel	1 family (grocery shopping, gone a total of 3 hrs by bus)	
Average costs for travel	$2.50 with range $0–6	$3 with range $0–6
Average food costs	$4.3 with range $0–10	$1 with range $0–6
Average lodging costs	$0	$0
Average other costs	$3.30 with range $0–25	$4.20 with range $0–25
Average days lost work	0.3 with range 0–8	0.2 with range 0–1
Average hours lost work	2.3 with range 0–8	2.7 with range 0–6
Average cost of lost work	$13 with range $0–40	$12 with range $0–20
Other costs	$3 for one family	
Lost work for second person	5 families	2 families
Average cost	$21 per family	$12.50 per family

Table 11 Family-based costs associated with diagnosis of hearing loss

Description of costs	Expense
Average cost per family that visited a clinic once (73%)	$21.00
Average cost per family that visited clinics twice (27%)	$33.50
Total costs to referred families if all families referred by teacher screener visit clinics: ($21*73%*235) + ($33.50*27%*235)	$5,728.00
Average costs per **screened** child if referred family costs based on teacher screener are averaged across all screened children [($21*73%*235) + ($33.50*27%*235)] / 1774	$3.23 per screened child
Average costs per child **referred** by teacher questionnaire if all families who are referred share average costs calculated above [($21*73%*235) + ($33.50*27%*235)] / 235	$24.38/referred child
Average costs per **diagnosed** child based on 6 of 235 diagnosed with hearing loss and all referred family costs are averaged across children diagnosed with hearing loss [($21*73%*235) + ($33.50*27%*235)] / 6	$954.50/child identified with hearing loss

7.5.2 Audiometric testing

Audiometric testing was done to evaluate the accuracy of the teacher-administered hearing screening questionnaire. Costs associated with the audiometric testing included those related to producing the materials, distribution, training, conducting the screening and managing follow-up. Data on the costs of conducting hearing screening were collected from teacher surveys, focus groups and interviews with staff in SETEDIS. Costs to families for diagnosis and follow-up included family time spent on travel and appointments, lost wages or other family income, transportation costs to clinics, lodging and meal costs, and other cost data identified during the focus groups.

Ecuadorian audiologists' salaries average $1,200 per month, or $60 per day. If each audiologist completed 8 schools, and training took one day, or 8 hours, the time allocation per school for training is 1 hour. Because it would be unlikely that audiologists contacted parents whose children failed screening, we presumed that teachers completed that task. The costs related to audiometric testing are presented in Table 12.

Table 12 School-based costs related to audiometric testing

Description of costs	Time	Expense
Training time for audiologists per school	1 hour	
Travel time	2 hours	
Screening time for 20 students (paperwork, screening, recording results) @ 20 minutes each	5 hours	
Travel costs (gas) at $2.10/gal, estimated 100 miles round trip, 20 miles per gallon		$10.50
TOTAL audiologist costs per classroom @ $60 per day	8 hours	$70.50 per day
Contacting parents if 32% failure rate (6.4 students) @ 20 mins each at teacher salary rate of $60 per day	2.13 hrs	$16.00
Audiology equipment per identified child		$0.625
TOTAL audiological cost per **screened** child ($97 / 20, 1774 total screened) + $0.625		$5.48/screened child
TOTAL per **referred** child (total cost / children referred or $97 / 6.4 + $0.625, 575 children should have been referred through audiometry)		$15.78/referred child
TOTAL audiological cost per **diagnosed** child if we assume 24 of 1,774 were diagnosed with hearing loss (Cost per screened child x 1,774 screened / 24 with hearing loss)		$405.06/child identified with hearing loss

Cost data for families whose child was referred for diagnosis would be the same as presented for the teacher-administered questionnaire.

7.5.3 Information related to expenses

The following costs would be calculated for families whose children were referred during the screening process using the actual costs shown in Table 12. Additional attribution of costs to families due to time lost has not been made. Only direct expenses are used in the following calculations (see Table 13).

Taken together, the cost of the audiological hearing screening and communication of the results ($5.48 per child) for 1,774 children during Phase 2 of the study was $9,722 ($5.48 x 1.774 = $9,722). The costs to families of participating in the diagnostic audiological evaluations was an additional $14,016. The total cost given families' expenses for diagnosis was $23,743 ($9,722 + $14,016). Given that 24 children were identified with permanent hearing loss based on the results of the teacher-administered hearing screening questionnaire, the cost per child identified with hearing loss was $989 and the average cost of just the audiometric testing was $5.48 per child.

Table 13 Family costs related to audiometric testing

Description of costs	Expense
Average cost per family that visited a clinic once (73%)	$21.00
Average cost per family that visited clinics twice (27%)	$33.50
Total costs to referred families if all families referred by audiological screening visit clinics ($21*73%*575) + ($33.50*27%*575)	$14,015.63
Average costs per **screened** child if referred family costs based on audiological screening are averaged across all screened children [($21*73%*575) + ($33.50*27%*575)] / 1774	$7.90 per screened child
Average costs per child **referred** by audiological screening if all families who are referred share average costs calculated above [($21*73%*575) + ($33.50*27%*575)] / 575	$24.38/referred child
Average costs per **diagnosed** child based on 24 of 575 children who were diagnosed with hearing loss and all referred family costs are averaged across children diagnosed with hearing loss [($21*73%*575) + ($33.50*27%*575)] / 24	$583.98/child identified with hearing loss

7.5.4 Differences in costs between methods

The differences in costs for each child diagnosed with hearing loss through the teacher questionnaire when compared to audiometer testing indicate that the teacher-administered hearing screening questionnaire cost 41 per cent more ([$823 – $548] / $584 = 0.41). However, the greater cost could be attributed to those not referred and diagnosed through the teacher screener when compared to testing with the audiometer. To explain, if only 6 children were diagnosed by the teacher questionnaire screening (with 5 of those 6 also diagnosed through testing with the audiometer), while 24 were diagnosed by testing with the audiometer, the costs to children with hearing loss and their families when hearing loss goes undiagnosed may be considerably higher than the costs of screening using audiometers.

7.5.5 Summary of cost analysis

The purpose of the study was to provide data about the efficacy of the teacher-administered hearing screening questionnaire. It was not intended to provide data on how to implement an alternative hearing screening approach. By collaborating with the Ecuadorian government, the policymakers had the opportunity to be involved and have buy-in, two important components when change is needed.

While audiometric screening would ideally be conducted through a two- or three-stage process, this study included only one test with the audiometer. This is because the point of the study was to evaluate the accuracy and effectiveness of the teacher-administered hearing screening questionnaire, and not to do a comparative evaluation of two fully developed hearing screening programmes. Nonetheless, the single audiometric test correctly identified 24 children with hearing loss, while the teacher-administered questionnaire only identified 6 of these children. The cost of the audiometric testing (including family costs for obtaining a diagnosis) was $989 ($405 + $584) per child diagnosed with hearing loss, while the teacher-administered questionnaire was $1,758 ($813 + $955).

However, these costs do not take into account the costs to children, family and society when hearing loss is not diagnosed. Because audiological screening provided greater accuracy in identifying children with hearing loss, the actual costs to families, children and society would be less when children are identified early and provided with appropriate intervention to help them access education and better employment options in the future.

8. Discussion of results

The results of this evaluation study revealed that the teacher-administered hearing screening questionnaire did not function well as a screening tool for first-grade children in public school programmes in Ecuador. Many of the children who failed the questionnaire passed audiometry, and many of the children who failed audiometry passed the questionnaire. This is a significant finding because the purpose of doing a screening test is to identify those individuals likely to have a problem and discover who should receive further testing. Furthermore, there are burdens to the family and the healthcare system when too many children with normal hearing receive further testing because they failed the hearing screening test. For example, if too many children with normal hearing fail the hearing screening test, some parents will unnecessarily miss work and incur additional expenses. Also, the healthcare system will be burdened with completing unnecessary tests which, in turn, reduces access for those individuals who really need the services.

8.1 Concerns related to internal validity

Inferences are said to be internally valid if we can be confident in concluding that two variables are causally related. In other words, is there convincing evidence that X causes Y, or is there a third variable (Z) that is responsible for what appears to be a causal relation between X and Y? This study was never intended to analyse the causal link between a specific intervention and an outcome. Instead, it was designed to evaluate whether a teacher-administered hearing screening questionnaire was an accurate and effective tool for identifying children with hearing loss. Thus, the classic application of internal validity is not really relevant.

It is, however, still important to know whether the main conclusion from the study that the teacher-administered hearing screening was not effective and accurate could be due to other extraneous or spurious factors. Listed below are the most likely threats to the 'internal validity' of that conclusion.

- *Audiometer was the wrong basis for comparison.* Given that screening audiometry has been used extensively and is recognised throughout the world as the gold standard of hearing screening (Bamford *et al.* 2007; AAA 2011; British Society of Audiology 2011), this is very unlikely. Furthermore, four times as many children actually diagnosed with hearing loss failed the audiometry as children who failed the teacher-administered questionnaire.

- *Teachers did not administer the questionnaire properly.* Although little is known about how teachers were trained to administer the questionnaire during 2012

(and parents and teachers in the focus groups voiced concerns about that training), the training during Phases 1 and 2 of the study was more detailed and systematic. Zone physicians were present during the training to observe and ensure that it was being done correctly.

- *Many children who failed the hearing screening tests did not complete diagnostic audiological evaluations.* Although only a very small number of children from the 2012 implementation of Tamizaje Auditivo Escolar were documented as having completed the diagnostic audiological evaluations, 56 per cent of the children who failed hearing screening completed diagnostic evaluations in Phase 2. This provided a large enough sample to be very confident about the results.
- *The results of the two approaches are too close to be confident.* The differences in the number of children who passed and failed the hearing screening by the teacher-administered questionnaire and by audiometric testing, respectively, were so large that statistical tests were not really needed (even though they were done). The probability of observing differences under the null hypothesis that both methods were equally effective was less than 1 in a million.

8.2 Concerns related to external validity

External validity asks the question whether these results are applicable to other settings and times. Because the results were gathered at three different times (original initiative in 2012, and Phases 1 and 2 in 2013) with very similar results, we can be confident that the differences in results between the teacher-administered hearing screening questionnaire and the audiometry will not change from one time to another.

The results of this study are also likely to be applicable to other settings in which young children are educated in similar ways in public school settings. Early identification of hearing loss in children is a worldwide concern, and a significant challenge in developing countries. Hearing loss affects 160 million children worldwide, and undiagnosed hearing loss results in significant developmental and social deficits, reduced academic and vocational opportunities, and increased burden on families and communities (Olusanya and Newton 2007; WHO 2014). Identification of hearing loss provides an opportunity to begin intervention and improve outcomes for children with hearing loss. In many countries, newborn hearing screening (NHS) has been implemented as a means to identify hearing loss early (Centers for Disease Control and Prevention 2009). However, NHS is not routine in developing countries where the majority of children with hearing loss reside (Swanepoel 2013; WHO 2013), creating a need for a low-cost mechanism to identify hearing loss in children.

Even though the importance of hearing loss identification is well recognised, countries face multiple health and social challenges, such as eradication of extreme poverty and hunger; reducing infant mortality rates; and improving maternal health, among others. Population-based hearing screening for children at any age is not a common practice, and existing hearing screening programmes for preschool and school-age children show a lack of uniformity and comprehensiveness in most developing countries.

Use of a questionnaire to identify hearing loss has been an attractive option because no costly equipment is needed, and training demands to administer the questionnaire are minimal (e.g. Newton *et al.* 2001). However, there is scarce evidence that

questionnaires are an effective screening tool to determine accurately which children need further follow-up testing, particularly in public school–based settings where large numbers of children are easily accessible for screening.

Given the importance of early identification of hearing loss for development, academic and future vocational success, there have been other attempts in various countries to use a questionnaire to screen for hearing loss (see Table 14). The results of our study are consistent with the bulk of evidence from those other studies, which lends confidence to the external validity of these results.

Implementation of a population-based hearing screening requires consideration of characteristics related to the population to be screened (e.g. age, geographic location, access to services). Centralised tracking is needed to determine if the system is effective, to identify problematic aspects, and to determine potential solutions based on ecological considerations. Because this study included only samples of school children accessible in public schools, with children in each school assessed on a single day, attendance and enrolment factors may have affected the accessible population in non-random but undetermined ways. However, given the large samples used in the study and the very large differences between the results of the teacher-administered questionnaire and the audiometric testing, it is extremely unlikely that these attendance and enrolment factors would have changed the conclusions from the study.

8.3 Implications for cost-benefit

Audiometric testing identified four times as many children with hearing loss as did the teacher-administered hearing screening questionnaire. Even though the cost of administering the questionnaire was relatively low, the costs to families and the healthcare system of completing audiological diagnostic evaluations for the massive number of false positives, and the costs to society and to individuals of not identifying the large numbers of false negatives, makes it clear that a teacher-administered hearing screening questionnaire is not a good choice as a hearing screening instrument for first-grade public school children in Ecuador.

Table 14 Studies on using a questionnaire to screen school-age children for hearing loss

Author (Year) Country	Ages (N)	Items	Administered	Type and Degree of Hearing Targeted by the Questionnaire	Results	Recommended Use
Studies in which authors recommended the use of a questionnaire						
Newton *et al.* (2001) Kenya	2.21–7.5 yrs (*N* = 855)	8 items	Completed by teachers, parents or community nurses	Bilateral hearing loss of moderate degree or greater	Sensitivity 100% (for 40 dB or greater loss), Specificity 75%	Yes
Olusanya (2001) Nigeria	6–7 yrs (*N* = 359)	Not reported	Physician interviewed parent	Permanent or conductive loss of at least 20 dB	Sensitivity 10%, Specificity 94%	Yes
Samelli, Rabelo and Chaparin (2011) Brazil	2–10 yrs (*N* = 214)	14 items	Evaluator interviewed parent	Slight to profound hearing loss classified by conductive or sensorineural)	Sensitivity 44%, Specificity 87%	Yes
Studies in which authors did not recommend the use of a questionnaire						
Hammond *et al.* (1997) Australia	4–5 yrs (*N* = 685)	10 items	Parent completed	Persistent hearing loss	Sensitivity 56%, Specificity 52%	No
Gomes and Lichtig (2005) Brazil	3–6 yrs (*N* = 133)	8 core items and age-specific questions and observations	7 trained volunteer screeners interviewed parents	Not specified	Questionnaire did not differentiate between children with middle ear disorders and those without disorders	No
Bu, Li and Driscoll (2005) China	6–12 yrs (*N* = 317)	34 items	Parent completed	At least moderate permanent or conductive hearing loss	Low agreement between audiometry and questionnaire; item hit rate 0.07 – 0.42; true negative rate 0.76 – 0.99	No
Li, Driscoll and Culbert (2009) China	6–13 yrs (*N* = 154)	11 items (yes/no)	Parent completed	At least moderate permanent or conductive hearing loss	Sensitivity 67%, Specificity 56%	No

9. Actionable findings for policy, implementation and research

9.1 Policy implications

The results of this study have important policy implications. In February 2014, researchers met with Ecuadorian officials to present and discuss the study findings. The initial rationale by the Ecuadorian Vice President's Office for pursuing a questionnaire-based screening as the solution for finding children with hearing loss was motivated by the belief that it would be low-cost, require minimal training, and could be easily implemented. There was also the untested assumption that it would be effective in identifying children with hearing loss, so that treatment could be provided and the consequences of hearing loss could be reduced. Because there was a very little data available to guide their decisions, the purpose of this study was to provide data that could be used to inform policy decisions about how best to screen young children for hearing loss in public school programmes.

It was clear from the study results that the questionnaire did not function well to identify children with hearing problems. However, the questionnaire did raise awareness about the importance of considering hearing when a child is struggling in school. Teachers and parents throughout the study expressed their appreciation and support for the government's efforts to identify and help children with hearing problems.

The hearing screening programme is scheduled to transition from SETEDIS to the Ministry of Health in July 2014. The Ministry of Health will then have primary oversight of the school-age hearing screening programme. It appears that the data from this study is so compelling that the Ministry of Health will be considering other options besides using a questionnaire as they continue their efforts to identify young children with permanent hearing loss.

9.2 Key lessons from the research process

The research process revealed several important lessons. It was essential for the stakeholders in Ecuador to be an integral part of the process because the purpose of the study was to obtain data about the efficacy of the questionnaire screening that could be used to make policy decisions. As part of our role, we facilitated the process of systematically investigating the efficacy of the questionnaire screening. However, in doing this, the process was driven by their goals and values. The Ecuadorian stakeholders gave high importance to identifying children with hearing loss so that these children can receive needed treatment and achieve academic success and later vocational success.

Because the data from Phase 1 of the evaluation was not what they expected (i.e. they thought the questionnaire would effectively identify children with hearing loss), we incorporated their desire to revise the questionnaire for further evaluation during Phase 2 of the study. This provided an opportunity to see if modifying the questionnaire and improving the process resulted in acceptable outcomes. When Phase 2 of the study was completed and the results continued to demonstrate that the questionnaire screening did not work well, the government officials, while disappointed, were able to take the objective information and are using that to explore alternative solutions that will better meet their central goal—

identifying childhood hearing loss so that treatment can be provided. It was important for our process to focus on their successes, which were impressive, and build our discussion from a strength-based perspective to support moving forward in a positive and constructive manner.

9.3 Questions for future research

Based on the findings from the study, we recommended the following actions for their consideration as they transition responsibility for the hearing screening programme for young children to the Ministry of Health.

1. Systematically explore alternative methods for identifying young children with hearing loss. Include maximising existing resources available, such as:
    a. evaluating how well the NHS programme is working and determining if the process needs improvement;
    b. requiring children to have an audiometric hearing screening at their local health centre before enrolling in school. This is a logical opportunity for a population-based screening using a reliable method, given that audiometry is available at health centres located conveniently throughout the country.
    c. considering hearing screening technologies currently being developed, such as smart phone applications. Smart phone applications are not currently available for purchase, but are an area of research in other developing countries.

The purpose of screening is to provide effective treatment for children identified with hearing loss. For this reason, the following suggestions were made:

1. Evaluate the appropriateness, accuracy and cost of current diagnostic procedures being used by local health clinics and hospitals for children suspected of having hearing loss.
2. Determine whether the current system for fitting of hearing technology is effective.

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Approximately 90 per cent of children with hearing loss are found in developing countries. If it is not detected early in life, children who are deaf or hard of hearing lag behind their peers in social and cognitive development as well as in the learning of languages.

This impact evaluation in Ecuador assesses the effectiveness of the teacher-administered hearing screening questionnaire *Tamizaje Auditivo Escolar* in public schools. It does this by comparing the results of the questionnaire against what is considered the international gold standard for hearing screening: pure tone audiological testing.

The study finds that the *Tamizaje Auditivo Escolar* programme fails to identify the majority of children with permanent hearing loss. The authors recommend that if the programme continues, significant systematic improvements need to be made in teacher training, protocol adherence, reducing follow up attrition, and expanding access to diagnostic services.

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