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Abstract

In this article we evaluate the effectiveness of ethnomathematics education among indigenous children: the JADENKÄ program. This intercultural bilingual program has been designed to strengthen the mathematical and ethnomathematical skills of the Ngäbe preschoolers in Ngäbe-Buglé, a *comarca* in Panama. The results of our experiment suggest that the program has improved the students' mathematical and ethnomathematical skills. The magnitude of the impact on mathematics, of 0.12–0.18 standard deviations (s.d.), is comparable to preschool programs that teach intercultural bilingual classes in low- and middle-income countries. In ethnomathematics, the impact is around 0.23 s.d. Additionally, and consistent with other studies, we find that JADENKÄ has a beneficial effect on the cultural identity of students. Second, results suggest that the effect of the program in ethnomathematics is stronger among Ngäbere-speaking students and for students whose teachers identify as Ngäbe. Finally, the program bolstered teachers' ethnomathematical skills and also their knowledge of the Ngäbere language and culture. Contrary to the views of some critics, we find that a well-designed ethnomathematics program can reduce the indigenous achievement gap without asking students to choose between their academic learning and their identity, culture, and language.

JEL codes: C21; I24; J15

Keywords: Ethnomathematics, Intercultural Bilingual Education, Randomized Controlled Trial

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Introduction

Studies of education tend to regard mathematics as a universal language of science that transcends cultural and language barriers (e.g., Cimen, 2014; Parker Waller and Flood, 2016). According to this school of thought, mathematics is a language of symbols, structures, and methods that are new and foreign to any novice, independent of culture. Other researchers embrace the idea that mathematics exists within cultural and social contexts (Parker Waller and Flood, 2016).

Ethnomathematics is a field inside mathematics education research that developed from this latter school of thought. The many definitions of ethnomathematics all share basic assumptions (Cimen, 2014). First, as a human creation, mathematics is not universal as traditionally believed (D'Ambrosio, 1985, Bishop, 1988). Second, anthropological, and historical studies (Ascher and D'Ambrosio, 1994; Gerdes; 1994; Barton, 1996, Rosa and Orey, 2005) support that, throughout human history, different cultural groups have created their own mathematical language. Across the world, diverse cultural groups have also developed ethnomathematics curricula to be used principally at the primary level (Rosa, Gavarrete, and Alangui, 2017). Third, findings in ethnomathematics are applicable to mathematical education research. A recent definition states that ethnomathematics is a line of study and research of mathematics education, which investigates the roots of mathematical ideas and practices, starting from the way individuals behave in different cultural groups (Rosa and Gavarrete, 2017). The debate around ethnomathematics has influenced research in several disciplines: anthropology, history, philosophy, and education. In education, many studies focus on the relationship between ethnomathematics and mathematics education in order to identify, publish, and promote new teaching methods that incorporate local cultural issues (Vithal and Skovsmose, 1997). One area of debate concerns the practical implementation of ethnomathematics ideas in the classroom and its impact on learning.

Those who advocate for ethnomathematics in the school curriculum offer four arguments. First, ethnomathematics builds on the knowledge that students bring to the classroom, allowing them to better understand the formal mathematics from their own, not yet formalized, knowledge (Boaler, 1993; Favilli, 2007; Adam et al., 2003; Sternberg, Lipka, Newman, Wildfeuer, and Grigorenko, 2006; Stillman and Balatti, 2000). Second, students who are exposed to other mathematical cultures and reflect on them can boost their self-esteem and motivation to learn (Powell and Frankenstein 1997). Third, integrating an ethnomathematics perspective into the teaching of mathematics attributes value to students' culture, which can improve their attitudes toward their own cultural heritage (Meaney, 2002; Rosa and Gavarrete, 2017). Fourth, imparting the skills students need to succeed within the two (or more) cultures they inhabit provides them with a sense of mastery and efficacy—self-confidence that improves learning in general (LaFromboise et al., 1993).

On the other side of the debate, there is skepticism about incorporating an ethnomathematics approach. First, critics argue that the approach can detract from integration and equity because students from majority groups will continue to learn the academic mathematics that allows them to compete in an increasingly mathematized world, while students from other cultures will be limited to local knowledge (Rowlands and Carlson, 2002; Skovsmose, 1994). Others emphasize implementation challenges. Given that there may be innumerable ways of understanding mathematics, it could be difficult to articulate ethnomathematical knowledge with school knowledge. In their view, the school should be the place where people are exposed to universalized knowledge, knowledge that provides a common language in a world of many and complex cultures (Rowlands and Carlson, 2002). Also, and contrary to the ethnomathematical stance (i.e., students have nonformalized mathematical skills before they start school), they argue that this knowledge is not important for learning school mathematics because all students are equally positioned to learn new knowledge (Rowlands and Carlson, 2004). Finally, some scholars worry that including ethnomathematics in school systems may inadvertently generate ethnic conflicts by strengthening cultural identities (Vithal and Skovsmose, 1997).

The theoretical debate has, however, scant quantitative evidence on the ethnomathematics approach (its implementation and outcomes) within formal school systems. Additionally, most empirical studies are based on small samples of students or schools (e.g., Adam, 2004; Amit and Abu Qouder, 2017). A notable exception is a randomized controlled trial (RCT) conducted in two regions in southwest Alaska, which examined the efficacy of two second-grade modules of a culturally based supplemental mathematics curriculum in 50 schools (Kisker et al., 2012). The results show that the use of ethnomathematics to teach Representation and Measurement as well as Grouping and Place Value boosted students' mathematics performance (0.82 and 0.39 s.d., respectively). The gains of Alaska Native students were significant (effect sizes of 1.00 and 0.33 standard deviations, respectively).

The aim of this article is to provide rigorous evidence on the effectiveness of an ethnomathematics education program. Unlike previous studies of ethnomathematics that describe small-scale classroom interventions, this article presents causal evidence on the impact of an ethnomathematics program on student learning. Causal evidence is fundamental for understanding the value of ethnomathematics. To achieve this objective, this article describes and evaluates the impact of JADENKÄ (pronounced *HA-den-go*), an intercultural bilingual mathematics program designed to increase the mathematical and ethnomathematical skills of the Ngäbe preschoolers in the *comarca* Ngäbe-Buglé.[1] To our knowledge, this is the first study to evaluate the effectiveness of an ethnomathematics intervention in preschool education through an RCT.[2] The program was designed by a team of experts in early mathematics pedagogy, Ngäbe mathematics, and language, Interactive Radio Instruction (IRI) methodology,[3] as well as

[1] Panama has ten provinces and three indigenous geographical areas (*comarcas*) with provincial status (Kuna Yala, Emberá-Wounaan, and Ngäbe-Buglé). A *comarca* is defined as an indigenous territory with a semi-autonomous political organization under the jurisdiction of the national government. Within the limits of this geopolitical-administrative region, the indigenous people, to a large extent, govern themselves under their own political system (Herlihy, 1995). Law 10 of 1997 created the *comarca* Ngäbe Buglé from the territory of Bocas del Toro, Chiriquí, and Veraguas, a concession by the government to the political pressure of the indigenous people united by the threats of exploited natural resources and environmental degradation. Its capital is Llano Tugrí (or Buabïti). It is inhabited by the Ngäbe and Buglé indigenous peoples as well as nonindigenous rural people; 154,355 people live in the *comarca* (according to the 2010 census). Its area is 6,968 km^2. The largest group, the Ngäbe, speak Ngäbere, while the smallest group, the Buglé, speak Buglere; both are part of the Chibchense language family. The Ngäbe constitute the largest indigenous population in Panama.

[2] There is evidence that the early childhood development of premathematical concepts is decisive for future mathematical understanding and problem-solving skills (e.g., Geary, Hoard, Nugent, and Bailey, 2013; Resnick, 1989). Additionally, Sylva et al. (2013) find that developing logical-mathematical notions in preschool generates a significant improvement in students' mathematical skills in the future.

[3] Interactive Radio Instruction (IRI) is a low-cost educational system that has proved effective in various contexts and with varied content, such as mathematics and literacy. The IRI methodology can be defined as a "distance education system that combines audio programs with active learning to improve the quality of education and teaching practices" (World Bank, 2005). It is based on means of audio transmission or radio broadcasting to address the content of each session, such as, for example, audio recorded on USBs, CDs or MP3s.

Ngäbe actors and singers.[4] Throughout the article, the concept "mathematics" is used to refer to the mathematics contents incorporated in the national curriculum of Panama and "ethnomathematics" for that which integrates Spanish and Ngäbere and uses the Ngäbe numerical system and cultural elements.

A wide spectrum of factors led the government of Panama to develop and implement the JADENKÄ program in the *comarca* Ngäbe Buglé. First, Panamanian third and sixth graders score below the Latin American regional average in mathematics achievement on the regional standardized learning assessment (TERCE, 2013).[5] A vast majority of Panamanian third graders scored at the lowest level of achievement in mathematics (Level 1)[6] (60.1 percent), surpassed only by Guatemala (60.2 percent), Paraguay (66.5 percent), Nicaragua (68 percent), and the Dominican Republic (84.8 percent). Second, in Panama vast learning gaps persist between indigenous and nonindigenous students. Among the countries participating in TERCE, Panama falls in the group with the greatest gaps in scores, both in mathematics and reading. In third grade, indigenous students (those whose mother identifies as indigenous) are 0.64 standard deviations below nonindigenous students in mathematics. In sixth grade the gap increases to 0.7 standard deviations (OREALC/UNESCO, 2017). Finally, the indigenous *comarcas* are at a disadvantage with respect to the rest of the provinces of Panama. The data from the national learning test (CRECER, 2018)[7] show that the three indigenous *comarcas* have the highest percentage of students at learning levels 0 and 1 in mathematics (very low and low respectively). In the specific case of the *comarca* Ngäbe Buglé, this percentage corresponds to 83 percent, while at the national level it is 49 percent. The *comarca* Ngäbe Buglé also has lower preschool enrollment rates compared with other provinces, as well as higher rates of over-age students, repetition, and dropout, both at the primary and secondary levels of education (UNICEF, 2019).

This study seeks to answer three sets of research questions. *Research Question 1 (RQ1):* What was the impact of JADENKÄ on mathematics and ethnomathematics learning? If so, were the effects heterogeneous according to the characteristics of the students, teachers, and schools? *Research Question 2 (RQ2):* Did the program have an impact on other relevant dimensions identified in the literature (e.g., oral comprehension of Spanish and Ngäbere and student's cultural identity); and *Research Question 3 (RQ3):* What mechanisms can explain the potential impact of the program? Changes in teacher skills? Our findings contribute to the research evidence on the effectiveness of an ethnomathematics curriculum and its potential to close the academic learning gap between indigenous students and their peers.

[4] The Organization of Ibero-American States (OEI) led the design of the program, in collaboration with the Inter-American Development Bank (IDB) and the Ministry of Education of Panama (MEDUCA), taking as a basis the national curricula for initial education of the Ministry of Education.
[5] TERCE (*Tercer Estudio Regional Comparativo y Explicativo*) was a learning assessment applied by UNESCO in 2013 to a sample of 15 Latin American countries: Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Dominican Republic, and Uruguay, plus the State of Nuevo León (Mexico). The assessment evaluated school performance in the third and sixth grades of primary education in Mathematics, Language (reading and writing), and, for sixth grade, in Natural Sciences.
[6] At level 1, students are able to perform only the simplest mathematical tasks, such as ordering natural numbers and comparing quantities, identifying basic geometric figures, identifying missing elements in simple sequences (graphs and numbers), or reading explicit data in tables and graphs.
[7] CRECER is a standardized assessment of student learning implemented in a census form that measures the reading, mathematics, and science competencies of students in the third and sixth grades.

Materials and Methods

JADENKÄ Intercultural Bilingual Preschool Mathematics

The JADENKÄ intercultural bilingual mathematics program was designed to improve learning among preschoolers in the Ngäbe Buglé region, the largest and most populous of Panama's indigenous *comarcas*. The preschools in the *comarca* follow the national curriculum, which encompasses a Mathematical Logical Thinking module that covers concepts aligned with those taught internationally in preschool and kindergarten. These include geometry, spatial relations, measurement, the ability to use and relate numbers, their basic operations, symbols and forms of expression, and mathematical reasoning to solve problems of daily life in children's social environment (MEDUCA, 2014). This national mathematics curriculum is intended to be taught through 60-minute daily lessons throughout the 200-day school year.[8] In developing the JADENKÄ program, all key content areas of the national curriculum had to be included in addition to any intercultural bilingual content, without expanding the actual classroom time for mathematics instruction.

Throughout the design of the JADENKÄ program, elders from the *comarca* were consulted about the program's proposed learning objectives, concepts, skills, and activities. These consultations were likely crucial to the acceptance of the program in the school communities. More valuable to the actual design process, however, was a mapping of the everyday use of mathematics by the Ngäbe, including traditions, songs, children's games, the use of mathematics and geometry in spirituality, cosmology, farming, art, and clothing. This mapping exercise provided inputs from a broader community group, which included women and youth. Based on the mapping, an expert on Ngäbe mathematics and language worked with pedagogues to structure the national preschool mathematics curriculum into five units that integrated the concepts of the national curriculum with ethnomathematical concepts: *What Are Numbers? Let's Work with Numbers! The Shape of Things! Let's Measure! And Where Is It?* For example, the *What Are Numbers?* unit covers both the mathematics numbering system in the national curriculum and the Ngäbe numbering system, with roots for numerals that are combined with classifiers. The learning objectives of the unit include skills in using 11 different roots, depending on the characteristics of the object in question.[9] Students learn that an orange should be classified as round and rendered *Kwa-ti-naran,* or "rounded thing-one-orange." They also learn that if that same orange is cut in half and is no longer round, its noun class changes, affecting the way it is counted. The shapes in the students' daily lives form the starting point of the unit *The Shape of Things!,* including names for items used in *Ngäbe* clothing, farming, and art. In the unit *Let's Measure!*, the linear concepts of time laid out in the national curriculum (e.g., before and after) are complemented with the Ngäbe notion of time as circular. Students learn to recognize seasonal patterns when different community activities should begin (e.g., harvesting specific crops and times for celebrations) and the links to the stages in nature for plants, animals, and insects.

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[8] In practice, schools close frequently, and even when open, students attend school fewer than the stipulated 200 days of instruction, owing to weather, illness, or a parent's perception that preschool is less important than more advanced grade levels.

[9] The Ngäbe numerical system combines linguistic markers with quantifiers classifying the elements being counted (e.g., shape: round, long, flat; arithmetical: multiplication, division, addition; human being, days of the month, money, fruits and vegetables). The combination implies that numerical symbols depend on, or rather have no meaning without, the quantifier. With eleven numbers ranging from 1 to 10 and 20 as the foundational link between the decimal and vigesimal bases, quantifiers are required for counting but do not affect arithmetical operations (Le Carrer, 2013)

As with teachers in the many intercultural bilingual education (IBE) schools throughout Latin America (Näslund-Hadley and Santos, 2021), teachers in the sample schools do not often come from the *comarca* or speak Ngäbere. An additional complication is that every classroom has a mix of monolingual students in Spanish or Ngäbere, as well as bilingual students. To implement JADENKÄ in this context, Ngäbe actors and singers were contracted to record 108 audio lessons that repeat all key concepts in Spanish and Ngäbere. Each audio has a duration of about 45 minutes, guiding the teacher in lesson delivery through instructions for activities, radio-theatre, mathematics stories, and songs. The audios are based on an inquiry- and problem-based pedagogical approach where students learn by working in groups to solve mathematical challenges under teacher guidance and sing and dance to songs that reinforce different mathematical concepts (e.g., numbers, geometric shapes, and spatial relations). Teachers were instructed to use the last 15 minutes of each class for postaudio activities designed to reinforce key concepts. Due to restrictions on the implementation of the national curriculum by MEDUCA, both the audio and the postaudio activities had to be implemented during the 60-minute duration of the mathematics lesson. Teachers were also instructed to use the audio lesson Monday through Thursday, and to use Friday class time for postaudio activities. (See Annex 1 for an example of a postaudio activity.)

Teachers received an initial two-day training in the use of audio lessons and postaudio activities. The initial training was complemented by coaching visits to support and monitor the implementation. On average, each teacher received 3.3 coaching visits during the 2018 school year and 4.8 for the 2019 school year. In addition to USB drives with the 108 audio lessons, each classroom was also equipped with a radio, a set of ethnomathematics story books in Ngäbere, a teacher guide, student worksheets, postaudio materials, and simple tangible materials such as counters.

The JADENKÄ pilot program described in this article was conducted during the 2018 and 2019 school years. In practice, school closures due to floods and cold weather, among other issues (e.g., logistical problems affecting the reception of materials, power outages), dramatically decreased the actual number of JADENKÄ lessons that were implemented. The actual implementation period was six months in 2018 and seven months in 2019. On average, 25.5 audio lessons were implemented in each classroom in 2018, far from the 108 lessons that constitute the full school year. In 2019, implementation improved by 50 percent to an average of 36.0 audio lessons per classroom. Although the Ministry of Education instructed all schools and teachers in the treatment group to participate, the average number of lessons implemented in classrooms varied widely, from 1 to 61 in 2018, and from 1 to 87 in 2019. In addition to the external factors described above, such as flooding, the different levels of implementation also reflect varying levels of interest in the program expressed by individual teachers and school directors.

Randomization

The JADENKÄ program was designed to be evaluated experimentally. Randomized evaluations (also called RCTs for randomized controlled trial) have recently gained prominence as a tool for measuring impact in policy research. In simple terms, RCTs are a type of impact evaluation method where study participants are randomly assigned to one or more groups. The groups receive different interventions, known as the treatment group or groups, and a comparison group that receives no intervention. Researchers then measure outcomes of interest in the treatment and comparison groups. Randomized evaluations make it possible to obtain a rigorous and unbiased estimate of the causal impact of an intervention (Gibson and Sautmann, 2021).

A stratified randomization strategy was used to assign the 373 schools in the sample to the treatment and control groups. This strategy first groups the schools into different strata and, within these strata, then randomly assigns them either to the treatment or control group. This method increases the probability that the groups are balanced, on average, compared with simple randomization seen in small samples (Bruhn and McKenzie, 2009). Two variables were used to generate the strata: first, the geographical location of the school (Bocas del Toro, Chiriquí, Veraguas, Nedrini, Kädri, and Ño Kribo); and, second, the type of education offered at the school: formal, CEFACEI, or both.[10] The final sample includes 125 schools in the control group and 248 schools in the treatment group. The evaluation was carried out in the same sample of schools for both school years (2018 and 2019) that is, those schools that took part in the program in 2018 continued to implement it in 2019 as well. Each year, however, a different cohort of students participated.[11]

Evaluation instruments

To carry out the baseline and post-treatment phases, we use standardized instruments that had been used on similar projects such as *Tikichuela* in Paraguay (Näslund-Hadley, Parker, and Hernandez-Agramonte, 2014) and *Pénsalo* in Costa Rica (Näslund-Hadley, Hernández-Agramonte, and Arias, 2018). Student assessments were applied by trained interviewers, using e-tablets. The evaluation is individual, which means that each interviewer administers one test to one student at a time. The battery of assessments applied to children includes the following instruments:

1. Mathematics*:* To measure mathematical skills, we adapted the Early Grade Mathematics Assessment (EGMA), developed by the United States Agency for International Development (USAID). This instrument has been applied and validated, offering robust assessments of learning in mathematics (RTI International, 2009). This assessment instrument emphasizes capturing skills such as discrimination and visual counting, selection of shapes, counting objects, selecting numbers, adding and subtracting, identifying geometric forms, and naming the numbers. For this evaluation, we used an adaptation validated in Panama by Innovations for Poverty Action (IPA) with the support of the Ministry of Education of Panama (MEDUCA).

2. ethnomathematics*:* We designed a set of specific questions to measure Ngäbe's own mathematical abilities in a preschool context, using classifiers, roots, and mathematical operations; basic components of ethnomathematics that a four- to five-year-old child might understand. Specifically, for the development of this module we had the advice of experts on the Ngäbe culture and mathematics.

3. Oral comprehension in Spanish: To measure oral comprehension, we used a question from the Early Grade Reading Assessment (EGRA), also developed by USAID. This measurement assumed that the use of methodologies based on interactive audios might affect listening comprehension (Näslund et al., 2014).

4. Oral comprehension in Ngäbere: The EGRA question in the Spanish version was adapted to a Ngäbere version. The paragraph used followed the same style as the EGRA in Spanish and was also contextualized towards objects close to the Ngäbe culture.

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[10] A CEFACEI (*Centros Familiares y Comunitarios de Educación Inicial*) is a nonformal preschool program serving children who are four to five years old. The CEFACEIs are operated by promoters chosen among the parents of the community and trained by personnel from the National Directorate of Initial Education of the Ministry of Education.
[11] The multigrade classrooms made it possible for some students to take part in the program for two years in a row.

5. Cultural identity: An intercultural bilingual approach to education could have an effect on cultural knowledge and cultural identity. To measure possible effects in this dimension, educators included a module with three areas related to cultural identity: knowledge, perception, and attitude (Sparks, 1992).

The average test application was 26 minutes, including sections that had to be answered only in Spanish (EGMA and EGRA-Spanish), only in Ngäbere (ethnomathematics, EGRA-Ngäbere), and others that could be answered in either of the two languages (rest of sections). The instruments were piloted with a sample of 100 students to verify that children understood and were able to solve the exercises. Along with student testing, data were collected on basic characteristics of preschoolers (e.g., gender, age, ethnicity, language). We also asked school principals to complete a questionnaire about perceptions (their perceptions about math teaching, classroom composition, self-perception, of community service, and of intercultural bilingual education), teachers (infrastructure and school equipment, perception of the teaching of mathematics in preschool, perception of intercultural bilingual education, and school climate), and parents (perception of student performance, socioeconomic context of the home, and allocation of time at home). These questionnaires were handed out in both treatment and control schools. In the baseline measurement (pretreatment), we applied the questionnaires filled out by principals, teachers, and parents, while for the end-line measurement (posttreatment), we implemented only the teachers´ questionnaire. The enumerators belonged to the Ngäbe community who were fluent speakers of both Spanish and Ngäbere.

Descriptive statistics of the sample and balance test

Experimental impact evaluations base their counterfactual identification strategy on the generation of comparable groups before the intervention (Kopper and Sautmann, 2021). Using the baseline data, the question of whether the treatment and control groups are statistically identical can be tested. Table 1 shows descriptive statistics of the sample and a t-test of the differences in the means (balance test) of pretreatment variables among students, teachers, and schools.

First, regarding students, we observed that 94.4 percent of them are considered Ngäbe by their teacher. However, most speak Spanish at home (72.7 percent). The rest speak Ngäbere or both languages. Regarding teachers, 91.3 percent are women, with an average age of 39 years. Unlike students, only 29.3 percent declare themselves Ngäbe. Consistent with this, 77.2 percent declare that they speak Spanish better, 4.8 percent Ngäbere and 17.5 percent both languages equally well. As in many rural areas of Latin America, a high percentage of teachers do not have an education degree (22.8 percent) (Bertoni et al., 2020). Finally, regarding schools, 73 percent of them are located in the *comarca* Ngäbe Buglé and 27 percent in the surrounding areas. Nearly 60 percent (59.5 percent) are unigrade (i.e., classrooms with students all at the same grade level) and their average size is 284 students, 37.5 percent of them declare they use an intercultural bilingual teaching methodology and 40 percent have teachers with training in this educational model. In 43.7 percent of the schools, the predominant language is Ngäbere. Finally, and probably explained by their geographical location, a high percentage have connectivity problems: 22.6 percent have no communication equipment (radio, telephone, or internet), 30.6 percent do not have electricity, and only 38 percent have an internet connection. The treatment and control groups have no significant differences in their characteristics.

At baseline, no statistically significant differences were observed in the main outcomes of JADENKÄ. Only in Oral Comprehension in Spanish, the treatment group scored 0.109 standard deviations over the control group. No significant differences were observed in teachers' pretreatment knowledge of ethnomathematics. Finally, treatment and control schools showed no significant differences in the degree of implementation of actions related to IBE. These results confirm that the post-treatment comparisons are unbiased estimations of the effect of the program.[12]

Econometric model

The JADENKÄ program aims to improve mathematics skills (i.e., the mathematics taught in Panama's regular curriculum) and ethnomathematics, therefore our main indicators are the mathematics and ethnomathematics scores of the students. Additionally, we explore the effect of the program on other dimensions of interest that, according to the literature, could be affected by the program. These dimensions are oral comprehension, both in Spanish and Ngäbere, as well as the student's cultural identity.

For the analysis of each of these dimensions, the total score was calculated and standardized using the following formula:

Equation 1

$$Zij = \frac{Xij - \mu_c}{\sigma_c}$$

where Xij represents the score of each student i in school j, μ_c is the mean of the control group score, and σ_c is the standard deviation of the control group score. Zij expresses the standardized score, that is, expressed in standard deviations from a normal distribution where the mean is 0. The standardization of the scores allows us to make comparisons using the standard deviations as a common unit. The mean of the control group is used because it represents the mean of the population in the absence of intervention. The standardization of scores is a common technique in education evaluations that allows us to compare studies that use different instruments (Kraft, 2020).

To estimate the effects of the program, we use a regression with the following specification:

[12] For several reasons (e.g., family migration, teacher turnover, school closings), some students measured at the baseline were not found in the post-treatment evaluation. To rule out that this reduction of the sample was related to treatment assignment, a regression model was estimated whose dependent variable was the number of students lost between the baseline and the end-line measurement and whose independent variable was the treatment status (Equation two). The results indicate that there are no significant differences between the two groups. Additionally, Table 1 was re-estimated considering only the observations that could be surveyed in the end-line measurement. Again, there is no evidence of imbalance between the two groups. The results of these exercises can be requested from the authors. In the case of the 2019 evaluation, it was not possible to implement a baseline, so a study of the balance of the sample could not be carried out. Given that most of the schools remained in the evaluation sample, we are assuming the balance in 2018 was similar in 2019.

Equation 2

$$Y_{is} = \mu_s + \beta T_{is} + \varepsilon_{is}$$

where Y_{is} is the post-treatment standardized score of the student *i* in the stratum *s*, μ_s is a stratum fixed effect and ε_{is} is the error. T_{is} equals 1 when the student receives the treatment, and 0 when it is part of the control group. β is the average difference between the scores of the students in the treatment group and those in the control group. In this and in all the specifications presented later, standard errors are clustered at the school level to avoid "over-rejection" (Bertand, Duflo, and Mullainathan, 2004). Following the impact evaluation literature, β is the Intention to Treat Effect (ITT) of the program. The ITT is an estimate of the effect of the program on those assigned to treatment, regardless of their take-up. In many cases, researchers and policymakers care about identifying the impact of the program offer on the population offered the program, even if some of them did not take it up, as this will resemble what may happen if the program is rolled out. For this reason, this estimator is also known as the "policy impact" of the program.

Since the number of audios implemented differs for each treated school, we also estimated the impact of the Treatment on the Treated (TOT) effect. Following Berlinski et al. (2021) and Angrist et al. (2021), we implemented an instrumental variables estimator of the impact of one audio session of JADENKÄ (per audio effect). The second stage takes the following form:

Equation 3

$$Y_{is} = \mu_s + \gamma N_{is} + \varepsilon_{is}$$

where N_{is} is the number of audios that the teacher of student *i* reports having implemented. In the first stage, we instrument[13] the endogenous variable N_{is} with the school-level randomized treatment variable T_{is}. In this case, γ measures the impact of each program audio on the student's outcome.

To improve the precision of the estimators and test their robustness, the effects are also estimated with the following specification:

Equation 4

$$Y_{is} = \mu_s + \beta_1 Y_{is,t-1} + \beta_2 T_{is} + \varepsilon_{is}$$

This model includes the student's standardized score at baseline as a control variable to reduce residual variance and improve statistical power (Imbens and Wooldridge, 2009). With the 2019 cohort, however, it will not be possible to conduct this analysis because no baseline data were collected.

Finally, to test the heterogeneity of the impact of the program, a model is estimated that interacts the treatment variable with characteristics of the students, schools, teachers, and families. Specifically, the following specification is estimated:

[13] Instrument involves estimating in the first stage a regression between the number of audios implemented (dependent variable) and the treatment variable (independent variable) and using the predicted value as control variable in the second stage. Randomized assignment of JADENKÄ allows us to use the treatment variable T_{is} as an instrument of N_{is}, because the characteristics of schools in the two groups are not correlated with anything else—such as ability or motivation—that may also affect the outcomes. More details on the instrumental variable estimator in Gertler et al. (2016).

Equation 5

$$Y_{is} = \mu_s + \beta_1 Y_{is,t-1} + \beta_2 T_{is} + \beta_3 C + \beta_4 T_{is} C + \varepsilon_{is}$$

where the variables are defined the same as in equations 2 and 3. C is a set of dummy variables that defines characteristics of the students (gender, spoken language, and baseline test performance), schools (type of school and location), teachers (teacher training, perception towards mathematics and ethnic identification), or student's tutor (educational level, language spoken at home, and whether they are native to the region). β_4 is the additional effect of the treatment for the category included in the model with respect to the one omitted. For the 2019 cohort, the model does not include the lagged score.

Results

RQ1: Impact of JADENKÄ on mathematics and ethnomathematics learning

(a) Global effects

Table 2 shows the average effect of JADENKÄ on the main outcomes of the program for the 2018, 2019 cohorts and both cohorts together. Given that there are schools in the treatment group for which we have no information regarding the last audio implemented, the table also shows the estimator of the ITT effect in the sample used to estimate the TOT effect.[14] In mathematics, we found in 2018 an ITT effect of 0.12 standard deviations (s.d.) of the treatment group over the control group. When we study the effect on ethnomathematical skills, a positive impact is again found, but of a larger magnitude. Treated students improve their ethnomathematical skills by 0.23 s.d. In 2019 we observe a similar trend, however. The magnitude of the coefficients is larger with mathematics, with an impact of 0.18 s.d. (that is, 0.06 deviations above what we found in 2018). We observe a similar result in ethnomathematics, with an impact of 0.22 s.d., similar to the 2018 result. The 2019 results suggest that better implementation can increase the effect of JADENKÄ on learning. With 10 additional audios on average, JADENKÄ gets an effect of 0.18 s.d. in mathematics in the 2019 cohort.

The results of the TOT effect allow an estimate of how much the impact of the program could increase by increasing the number of audios implemented. In mathematics for example, an increase of 10 implemented audios would have an effect of 0.05-0.07 s.d. (TOT x 10). In ethnomathematics the same value would be 0.06-0.1 s.d. The larger effect in the 2019 cohort could also be explained by an improvement in the quality of implementation, since in 2019 several teachers had already participated in the program and because some students may have been exposed to two years of lessons**.** Following the categorization in Kraft (2020), the JADENKÄ program obtains an effect in mathematics of medium magnitude, and an effect in ethnomathematics of large magnitude.[15] Evans and Yuan (2020) find that the

[14] We compared the characteristics of students with information on the number of audios implemented in their school versus those without information. We did not find significant differences in pretreatment variables, except for a better oral comprehension of Spanish in the sample with information.

[15] Kraft (2020) reviews 750 experimental evaluations in education. Based on the distribution-of-effect sizes that he finds, he proposes the following categorization: an effect smaller than 0.05 standard deviations should be considered small, an effect between 0.05 and 0.19 should be considered medium, and an effect of 0.20 or larger should be considered large.

median-effect size for 156 experimental and 143 quasi-experimental studies implemented in low- and middle-income countries was 0.10 standard deviations.

In table 3 we compare the ITT effect of the program on different mathematical skills measured in EGMA. It can be observed that for the two cohorts, an effect is found in the abilities of identifying the predecessor and successor number, number selection and shapes. The impacts are of a similar magnitude for both cohorts. However, for the 2019 cohort we found an additional effect on the ability to name numbers, discriminate quantities, and add and subtract. This result suggests that an additional explanation of the larger magnitude of the effect in the 2019 cohort with respect to that of 2018 is because the larger number of skills were developed.

(b) Subgroup effects

This subsection explores the heterogeneity of the program's ITT effects on the main outcomes of interest (mathematics and ethnomathematics) among various subgroups of the sample, using the specification in Equation 5. This analysis makes it possible to determine whether certain characteristics of the students, their school context, their teachers, or their households result in a differentiated impact of the program.

Table 4 presents the analysis of heterogeneity according to the student's gender, the language they speak, and their performance on the baseline test. The results suggest that the effect of the program, both in mathematics and ethnomathematics, is independent of the student's gender and whether they were below or above the mean score at the baseline since the coefficients of the interactions are not statistically significant. Unlike the above, the effect of JADENKÄ in ethnomathematics is lower for students who only speak Spanish compared to those who speak Ngäbere or Ngäbere and Spanish equally (-0.35 s.d. in 2018). This result suggests that having a linguistic base could boost the learning effect of the ethnomathematics component. This difference is not found, however, in the 2019 cohort. One possible explanation is that, unlike parents, teachers cannot correctly identify the language best spoken by the student. Another option is that the greater exposure to the program in 2019 has particularly benefited those students who speak only Spanish.

Although most of the schools are in the *comarca* Ngäbe-Buglé, one in four is in the surrounding areas. Schools within and in the surrounding area of the *comarca* may have different resources or teacher and student characteristics. Therefore, we explore differential effects between the two groups of schools. In this case, we do not find differences between the students who attend the two types of school, both in mathematics and in ethnomathematics. These results strengthen the external validity of our analyses.[16]

Table 5 shows the estimated impact of the program according to teacher training, teachers' perception of mathematics, and their ethnic identification. The results show no significant differences in the effects of the program according to teacher training. In ethnomathematics, however, for the 2018 cohort, we observe a larger effect for preschoolers taught by teachers without training. On the other hand, the ethnic identification of the teacher (i.e., if they identify as Ngäbe or another ethnic group) also seems to have an interaction with the program. While there are no significant differences in mathematics, when the teacher identifies as Ngäbe, his or her students obtain higher scores in ethnomathematics. The difference was a statistically significant 0.39 s.d. in 2018 (0.31 s.d. with both cohorts combined). According to the monitoring data of the program, the Ngäbe teachers achieved a higher average level of audios

[16] The table with the results of the estimation can be requested from the authors.

implemented in 2018, which suggests that this differentiated effect may be due to a motivational aspect or a better use of the program due to their condition as Ngäbe. Finally, we did not observe significant differences according to the teacher's perception of mathematics.

Finally, table 6 presents the program results for 2018 by the tutor's educational level (the tutor is responsible for representing the student at school), the language the tutor speaks at home, and whether the tutor originates from the *comarca.*[17] In general, we observe program impacts are unrelated to the tutor's educational level and his belongingness to the *Comarca*. By way of contrast, students whose tutor speaks to them more in Ngäbere, or Spanish and Ngäbere alike, obtain higher scores in ethnomathematics than those students whose tutor speaks to them mainly in Spanish (≈0.3 s.d.).

RQ2: Impact of JADENKÄ on students' oral comprehension of Spanish and Ngäbere and cultural identity

Even though JADENKÄ seeks to improve students' mathematical and ethnomathematical skills, the literature suggests the program could bring other, secondary, outcomes. For example, the fact that JADENKÄ combines Spanish and Ngäbere content could strengthen oral comprehension in both languages (Näslund-Hadley, Parker, and Hernandez-Agramonte, 2014). Also, the program's emphasis on the use of ethnomathematics and Ngäbere, as well as the inclusion of content related to the Ngäbe culture, could affect the students' cultural identity in positive ways, understood as knowledge, preferences, and attitudes. To explore these results, we carried out the same analysis presented in table 2 but applied to the indicators of listening comprehension in Spanish, in Ngäbere, and an index of cultural identity. The results are, again, for the 2018 and 2019 cohorts and both cohorts together. Results are presented in table 7.

First, we did not find significant effects of JADENKÄ on listening comprehension in Spanish or Ngäbere for any of the cohorts. We can observe, however, that the students who participated in the program obtain a higher score in cultural identity, with a magnitude of 0.14–0.16 s.d. with respect to the control group. This impact is found again in the 2019 cohort, with a similar magnitude (0.12 s.d.), which indicates that the effect of the program is consistent over time. According to the results of the TOT effect, an increase of 10 implemented audios would have an effect of 0.05–0.06 s.d. in the cultural identity of the students. These results are also consistent with those found in the qualitative evaluation of the program,[18] where we observed a higher use and valuation of Ngäbe cultural elements in the treated schools (e.g., the *Nagua*, her traditional dress, the *Totuma*, a traditional Ngäbe container, and the traditional dance *Jeki*). Additionally, a greater use of Ngäbere was observed as a learning dynamic and to give instructions during classes.

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[17] This analysis is performed only for the 2018 cohort; there is no baseline for the 2019 cohort.

[18] To complement the JADENKÄ impact evaluation, we implemented a qualitative evaluation of the program in both cohorts (2018 and 2019). To do this, we conducted class observations and semistructured interviews with several educational actors (teachers, directors, families, and tutors of the program), with the aim of exploring how the classes were developed for the control and treatment groups, as well as to explore the implementation of the intervention. The study was conducted in 22 schools chosen randomly from the total sample. To be more representative, the schools were chosen considering the balance by treatment (8 from the control group and 14 from the treatment group), geographic area (10 in the *comarca* and 12 in a neighboring area), and type of preschool (13 from formal education and 9 from nonformal education). To analyze how the schools in the control group would carry out a math class, teachers were asked to prepare a class for the day of the visit. Detailed results of the qualitative evaluation can be requested from the authors.

RQ3: Impact of JADENKÄ on teachers

In this section, to study a possible channel through which the program may have affected learning, we analyze the impact the program had on teachers. Recent experimental evidence shows that higher-quality teachers improve student learning in early literacy, mathematics, and executive function, considering abilities such as working memory, attention, and cognitive flexibility (Araujo, Carneiro, Cruz-Aguayo, and Schady, 2016).

Table 8 presents the results of estimated program impacts on various dimensions related to the teacher, dimensions that could be affected by the program. These are based on the specification in Equation 2 at the teacher level. First, including the JADENKÄ program may have increased the time allocated to mathematics. This is because even though the activities should have taken place during the 60-minute daily mathematics lesson, the teachers may have extended the class to comply with the national curriculum while implementing other program activities. The results show no significant differences in the number of hours of mathematics per week reported by teachers in treatment and control schools. In this way, the effects of the program would be related to the change in the methodology and the contents of the lesson rather than to more hours of instruction.

On the other hand, the program may have facilitated the teaching of mathematics and ethnomathematics for teachers, which, in turn, may have improved perceptions about teaching these subjects. To test this hypothesis, we created an index of perception about mathematics and bilingual intercultural education, based on a Likert scale on statements related to both dimensions. The results showed no statistically significant effects in either dimension.

Finally, the JADENKÄ program introduces the Ngäbe culture in the classroom through exposure and practice of the program contents. Therefore, it is plausible that the program may have affected teachers' knowledge of the culture. To test this hypothesis, three modules were included in the teachers' survey to measure their knowledge of the Ngäbere, ethnomathematics, and Ngäbe cultural objects. The results indicate that the teachers boosted their knowledge of Ngäbere words (0.56 s.d. in 2018 and 0.69 s.d. in 2019) and culture (0.56 s.d. in 218 and 0.72 s.d. in 2019), as well as their knowledge of ethnomathematics (0.56 s.d. in 2018 and 0.67 s.d. in 2019). Yet we observe an increase in their knowledge of Ngäbe objects, but only when we add the data from both cohorts, which suggests there is an effect, but that the sample size is not enough to detect when we disaggregate per cohort.

Discussion

In this article we describe and evaluate the impact of JADENKÄ, an intercultural bilingual mathematics curriculum program designed to strengthen the mathematical and ethnomathematical skills of Ngäbe preschoolers in the *comarca* Ngäbe-Buglé in Panama. To our knowledge, this is the first study to evaluate the effectiveness of an ethnomathematics intervention in preschool education through a randomized controlled trial design. It is also the first to assess the effect of an intervention on the specific mathematics skills of indigenous preschoolers in addition to that on the mathematics included in the national curriculum. With this, we are providing rigorous, at-scale experimental evidence on the effectiveness of an ethnomathematics school program.

Our results show that the program has a beneficial impact on the mathematical and ethnomathematical skills of students. The magnitude of the impact on mathematics (0.12-0.18 s.d.) is comparable to other bilingual and IBE preschool mathematics programs implemented in low- and middle-income countries. The "Mimate" program in Peru saw a rise of 0.12 standard deviations in mathematics learning among Quechua-speaking preschoolers (Bando, Näslund-Hadley, and Gertler, 2019; Gallego et al., 2019). The "Tikichuela" program in Paraguay increased mathematics learning by on average 0.21 standard deviations, with slightly more pronounced effects among Guaraní-speaking students, compared with their Spanish-speaking peers (Bando et al., 2019; Näslund-Hadley, Parker, and Hernandez-Agramonte, 2014). it is lower, however, than improvements reported by Kisker et al. (2012) in Alaska (0.82 and 0.39 s.d. for two ethnomathematics modules). In any case, the impact of an education intervention may be different in high-income countries.

Qualitative evidence suggests that the positive impact of JADENKÄ could be attributed to an improvement in the qualitative aspect of the classes. For example, class observations in a few schools showed more difficult content was presented, with classroom discussion of more varied topics, such as spatial relationships and the characteristics of objects in the treated schools. Improvements were also observed in the teaching strategy, including more hands-on discovery and time for critical thinking and mathematical talk. The qualitative evidence also highlighted the more effective use of materials in JADENKÄ classrooms and an improved classroom climate. Since the lessons are play-based, with singing and dancing, student and teacher attitudes toward mathematics improved. So, contrary to the positions of some critics of the implementation of an ethnomathematics curriculum in schools, our findings indicate that a program using local-culture can also have positive effects on the mathematical content in the national curriculum. Empirical studies of the complementarities between mathematics and ethnomathematics and the mechanisms at work in the intervention are a subject for future research. Additionally, and consistent with other studies (e.g., Falbo and DeBaessa, 2006; Amit and Abu Qouder, 2017), we found that JADENKÄ has a beneficial effect on the cultural identity of students. In this way, the program might be able to close the achievement gap without asking students to choose between academic learning and identity, culture, and language.

When we analyze the heterogeneity of the impact, we find that the positive effect of the program in ethnomathematics is higher among students who speak Ngäbere, or Ngäbere and Spanish equally, and for those whose teacher identifies as Ngäbe. This result suggests that having a linguistic base could boost the learning effect of the ethnomathematics component. These findings coincide with the belief among some teachers in treated schools. They recognize the importance of incorporating Ngäbe and Ngäbe mathematics but lack the knowledge required to teach lessons in this language. Additionally, the program strengthened the teachers' abilities and boosted both their ethnomathematical skills and their knowledge of Ngäbere and the Ngäbe culture. This finding indicates that the program improved not only the mathematical skills of students but also the capacities of teachers to implement a curriculum that incorporates elements of the students' local culture. The latter finding is key in view of the weakness of many IBE policies implemented in Latin America: the teachers lack knowledge of their students' language and culture (López, 2020). The bottom-up approach of the program, based on working with the Ngäbe people (political, educational authorities, professionals, etc.), is also important for achieving this objective.

The evaluation also reveals the limitations and challenges of implementing IBE in a developing country context. Addressing these implementation challenges could improve similar programs in the future. While

JADENKÄ succeeded in the short term, during implementation, medium- and long-term effects will have to be evaluated to see if academic gains persist beyond preschool. Also, more research is needed to understand the mechanisms at work in the program and its potential effects in urban and other educational settings where policy implementation can differ from those used in the experiment. JADENKÄ is currently being scaled vertically, to higher grade levels in the *comarca* Ngäbe-Buglé, and horizontally, to other indigenous *comarcas* in Panama and to Quechua preschoolers in Peru.

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Tables and Figures

Table 1. Descriptive statistics of the sample and balance test of pretreatment variables

	Control (C)	Treatment (T)	Overall	(C) - (T)	p-value from orthogonality test (*)
Students					
Mathematics (s.d.)	0.000	0.035	0.023	-0.035	0.582
	(0.048)	(0.040)	(0.031)	(0.063)	
Ethnomathematics (s.d.)	0.000	0.028	0.019	-0.028	0.691
	(0.059)	(0.040)	(0.033)	(0.071)	
Oral comprehension in Spanish (s.d.)	0.000	0.109	0.073	-0.109	0.052
	(0.043)	(0.036)	(0.028)	(0.056)	
Oral comprehension in Ngäbere (s.d.)	0.000	0.007	0.004	-0.007	0.907
	(0.042)	(0.038)	(0.029)	(0.057)	
Cultural identity (s.d.)	0.000	0.041	0.027	-0.041	0.529
	(0.053)	(0.037)	(0.030)	(0.064)	
Age	5.500	5.492	5.495	0.007	0.843
	(0.030)	(0.020)	(0.017)	(0.036)	
Female (%)	0.540	0.561	0.554	-0.021	0.708
	(0.045)	(0.031)	(0.026)	(0.055)	
Language spoken at home: Spanish (%)	0.719	0.731	0.727	-0.012	0.674
	(0.023)	(0.016)	(0.013)	(0.028)	
Language spoken at home: Ngäbere (%)	0.212	0.213	0.213	-0.002	0.944
	(0.019)	(0.013)	(0.011)	(0.023)	
Language spoken at home: Spanish and Ngäbere (%)	0.069	0.056	0.060	0.013	0.325
	(0.011)	(0.008)	(0.006)	(0.013)	
Ngäbe student (reported by teacher) (%)	0.939	0.946	0.944	-0.006	0.742
	(0.016)	(0.010)	(0.008)	(0.019)	
N	2275	4560	6835	6835	

Teachers					
Ethnomathematics knowledge (s.d.)	0.000	0.043	0.030	-0.043	0.588
	(0.066)	(0.045)	(0.037)	(0.079)	
Female (%)	0.915	0.912	0.913	0.003	0.918
	(0.026)	(0.017)	(0.014)	(0.031)	
Age	38.619	38.567	38.583	0.052	0.959
	(0.824)	(0.586)	(0.477)	(1.012)	
Best spoken language: Spanish (%)	0.756	0.778	0.772	-0.022	0.602
	(0.036)	(0.025)	(0.021)	(0.042)	
Best spoken language: Ngäbere (%)	0.050	0.047	0.048	0.003	0.894
	(0.017)	(0.013)	(0.010)	(0.022)	
Best spoken language: Spanish and Ngäbere (%)	0.188	0.169	0.175	0.019	0.628
	(0.032)	(0.021)	(0.018)	(0.038)	
Best spoken language: Other (%)	0.006	0.006	0.006	0.001	0.923
	(0.006)	(0.004)	(0.003)	(0.007)	
Ngäbe (self-declared) (%)	0.331	0.276	0.293	0.055	0.234
	(0.040)	(0.027)	(0.023)	(0.047)	
No teacher title (%)	0.246	0.220	0.228	0.026	0.603
	(0.042)	(0.026)	(0.022)	(0.050)	
N	178	387	565	565	
Schools					
School inside comarca Ngäbe Buglé (%)	0.763	0.714	0.730	0.049	0.331
	(0.040)	(0.030)	(0.024)	(0.051)	
School has formal preschool (%)	0.680	0.720	0.706	-0.040	0.466
	(0.046)	(0.031)	(0.026)	(0.055)	
School has non-formal preschool (e.g. CEFACEI) (%)	0.476	0.459	0.465	0.017	0.781
	(0.049)	(0.035)	(0.028)	(0.060)	
School has pre-K education (%)	0.729	0.705	0.712	0.024	0.717
	(0.054)	(0.037)	(0.031)	(0.066)	
School has K education (%)	0.971	0.946	0.954	0.025	0.409
	(0.020)	(0.019)	(0.014)	(0.030)	
Monograde school (%)	0.610	0.587	0.595	0.023	0.682
	(0.045)	(0.032)	(0.026)	(0.055)	
Total enrollment	282.940	285.167	284.439	-2.228	0.947
	(23.524)	(20.251)	(15.632)	(33.376)	
School uses Intercultural Bilingual methodology (%)	0.362	0.381	0.375	-0.019	0.734
	(0.045)	(0.031)	(0.026)	(0.055)	
School has teachers with IBE training (%)	0.459	0.373	0.402	0.086	0.131
	(0.048)	(0.032)	(0.027)	(0.057)	
Intercultural Bilingual Education (IBE) index	2.420	2.421	2.421	-0.001	0.993

	(0.045)	(0.037)	(0.029)	(0.061)	
Predominant language: Ngäbere (%)	0.466	0.424	0.437	0.042	0.458
	(0.047)	(0.032)	(0.026)	(0.056)	
Technological equipment quality index	2.337	2.389	2.371	-0.053	0.455
	(0.059)	(0.040)	(0.033)	(0.070)	
School does not have communication equipment (%)	0.228	0.226	0.226	0.003	0.958
	(0.039)	(0.027)	(0.022)	(0.048)	
School has no electricity supply (%)	0.299	0.309	0.306	-0.009	0.855
	(0.043)	(0.030)	(0.024)	(0.052)	
School has internet connection (%)	0.402	0.369	0.380	0.032	0.555
	(0.046)	(0.031)	(0.026)	(0.055)	
N	118	243	361	361	

(*) p-values from a t-test of the differences of the means of each variable.
School variables are reported by principal.
Type of education B102 variables may not add up to one because a school may have more than one type.

Technological equipment includes computers, printers, projectors, photocopiers, televisions, video players, slide projectors, audio equipment, cameras, and video cameras. The index varies between 1 (lowest quality) and 3 (highest quality).
Intercultural Bilingual Education (IBE) index is constructed from the actions implemented by the school in 4 dimensions: elaboration of educational plans with bilingual intercultural education, teacher training, enrichment of pedagogical materials and interaction between the school, the community, and the students. The minimum value of the index is 1 (absence of actions) and 4 (constant implementation of actions).

Table 2. Impact of JADENKÄ on main outcomes, 2018, 2019, and both years

	2018				2019		Both years	
	Mathematics	Ethno-mathematics	Mathematics	Ethno-mathematics	Mathematics	Ethno-mathematics	Mathematics	Ethno-mathematics
Intention to Treat Effect (ITT)	0.12*	0.23***	0.12**	0.23***	0.18***	0.22***	0.16***	0.23***
	(0.06)	(0.07)	(0.05)	(0.07)	(0.06)	(0.07)	(0.05)	(0.05)
N	2,518	2,518	2,518	2,518	3,246	3,246	5,764	5,764
Per-audio Effect (TOT)	0.007***	0.010***	0.007***	0.010***	0.005***	0.006***	0.006***	0.008***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
N	2,216	2,216	2,216	2,216	2,699	2,699	4,915	4,915
Intention to Treat Effect (ITT)	0.19***	0.25***	0.18***	0.25***	0.16***	0.21***	0.17***	0.23***
with TOT sample	(0.07)	(0.08)	(0.05)	(0.08)	(0.06)	(0.08)	(0.05)	(0.06)
N	2,216	2,216	2,216	2,216	2,699	2,699	4,915	4,915
Mean of implemented audios	26.4	26.4	26.4	26.4	33.6	33.6	30.3	30.3
Controls	No	No	Baseline	Baseline	No	No	No	No

Notes: The table reports the average difference. The scores have been normalized with respect to the distribution of the control group, therefore, the mean of the control group is 0. The standard errors (in brackets) are grouped at the school level. All models include strata fixed effects. The number of observations is lower for the TOT estimate because not all teachers report the information about the last audio implemented. *, **, *** indicate that the coefficients are statistically significant at a confidence level of 0.10, 0.05 and 0.01 respectively.

Table 3. Impact of JADENKÄ in mathematics (ITT effect) by learning areas 2018, 2019, and both years

	Oral counting	Count objects	Name numbers	Discriminate quantities	Identify predecessor and successor	Number selection	Addition and subtraction	Shapes	Spatiality
Panel A. 2018									
Intention to Treat Effect (ITT)	0.01	-0.00	0.03	0.03	0.16**	0.10*	0.07	0.17***	0.11**
	(0.05)	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.07)	(0.06)	(0.05)
N	2,518	2,518	2,518	2,518	2,518	2,518	2,518	2,518	2,518
Panel B. 2019									
Intention to Treat Effect (ITT)	0.10*	0.06	0.12**	0.15***	0.17***	0.14**	0.16***	0.17***	-0.02
	(0.05)	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.05)
N	3,246	3,246	3,246	3,246	3,246	3,246	3,246	3,246	3,246
Panel C. Both years									
Intention to Treat Effect (ITT)	0.06	0.03	0.08*	0.10**	0.16***	0.12***	0.12**	0.17***	0.04
	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.04)
N	5,764	5,764	5,764	5,764	5,764	5,764	5,764	5,764	5,764
Controls	No	No	No	No	No	No	No	No	No

Notes: The table reports the average difference. The scores have been normalized with respect to the distribution of the control group, therefore, the mean of the control group is 0. The standard errors (in brackets) are grouped at the school level. All models include strata fixed effects, and asterisks *, **, *** indicate that the coefficients are statistically significant at a confidence level of 0.10, 0.05 and 0.01 respectively.

Table 4. Impact of JADENKÄ (ITT effect) according to student characteristics

	2018		2019		Both years	
	Mathematics	Ethno-mathematics	Mathematics	Ethno-mathematics	Mathematics	Ethno-mathematics
Panel A. Student gender						
Treatment	0.12*	0.17*	0.17**	0.22***	0.16***	0.20***
	(0.06)	(0.09)	(0.07)	(0.08)	(0.06)	(0.06)
Woman	-0.09**	0.04	-0.13***	0.07	-0.13***	0.05
	(0.05)	(0.07)	(0.05)	(0.06)	(0.04)	(0.05)
Treatment x Woman	0.00	0.12	0.02	0.01	0.00	0.06
	(0.06)	(0.09)	(0.06)	(0.07)	(0.05)	(0.06)
N	2,518	2,518	3,246	3,246	5,764	5,764
Panel B. Language spoken by the student						
Treatment	0.19**	0.43***	0.27*	0.31**	0.20**	0.37***
	(0.08)	(0.11)	(0.15)	(0.15)	(0.09)	(0.09)
Speaks only Spanish	0.15*	-0.01	0.34***	-0.26**	0.26***	-0.14
	(0.08)	(0.11)	(0.13)	(0.13)	(0.08)	(0.09)
Treatment x Speaks only Spanish	-0.10	-0.35**	-0.10	-0.11	-0.03	-0.19*
	(0.10)	(0.15)	(0.16)	(0.16)	(0.10)	(0.11)
N	1,425	1,425	3,246	3,246	4,671	4,671
Panel C. Students' score in the baseline test						
Treatment	0.15	0.21	-	-	-	-
	(0.06)	(0.09)	-	-	-	-
Student above median score	0.08	0.23	-	-	-	-
	(0.08)	(0.09)	-	-	-	-
Treatment x Student above median score	-0.05	0.06	-	-	-	-
	(0.07)	(0.11)	-	-	-	-
N	2,518	2,518	-	-	-	-
Controls	Baseline	Baseline	No	No	No	No

Notes: The table reports the average difference. The scores have been normalized with respect to the distribution of the control group, therefore, the mean of the control group is 0. The standard errors (in brackets) are grouped at the school level. All models include strata fixed effects, and asterisks *, **, *** indicate that the coefficients are statistically significant at a confidence level of 0.10, 0.05 and 0.01, respectively. For 2018 we use the linguistic identification provided by the student's parents, while for 2019 the one provided by the teacher. Reference category for Panel B: Student speaks Ngäbere or Ngäbere and Spanish equally. Reference category for Panel C: First quartile. For the 2019 cohort we cannot implement this analysis for lack of baseline information.

Table 5. Impact of JADENKÄ (ITT effect) according to teacher characteristics

	2018		2019		Both years	
	Mathematics	Ethno-mathematics	Mathematics	Ethno-mathematics	Mathematics	Ethno-mathematics
Panel A. Without preschool training						
Treatment	0.11	0.07	0.16	0.14	0.15*	0.11
	(0.08)	(0.11)	(0.10)	(0.12)	(0.08)	(0.08)
Without preschool training	-0.07	-0.21*	-0.04	-0.09	-0.06	-0.13
	(0.10)	(0.11)	(0.10)	(0.12)	(0.08)	(0.09)
Treatment x Without preschool training	0.04	0.33**	0.04	0.12	0.02	0.21*
	(0.11)	(0.15)	(0.12)	(0.15)	(0.10)	(0.11)
N	2,410	2,410	2,930	2,930	5,340	5,340
Panel B. Perception about mathematics						
Treatment	0.15*	0.21*	0.17**	0.23**	0.18***	0.22***
	(0.08)	(0.12)	(0.08)	(0.10)	(0.07)	(0.08)
Positive perception	0.04	0.06	0.12	0.01	0.12	0.02
	(0.10)	(0.13)	(0.09)	(0.12)	(0.08)	(0.09)
Treatment x Positive perception	-0.09	-0.10	0.05	-0.02	-0.02	-0.03
	(0.12)	(0.16)	(0.11)	(0.15)	(0.10)	(0.11)
N	2,126	2,126	2,930	2,930	5,056	5,056
Panel C. Ngäbe teacher						
Treatment	0.12*	0.14	0.18**	0.12	0.15**	0.14**
	(0.07)	(0.09)	(0.07)	(0.09)	(0.06)	(0.07)
Ngäbe teacher	-0.11	-0.05	-0.23**	-0.01	-0.28***	-0.03
	(0.10)	(0.13)	(0.11)	(0.16)	(0.09)	(0.10)
Treatment x Ngäbe teacher	0.11	0.39***	0.10	0.26	0.12	0.31***
	(0.11)	(0.15)	(0.12)	(0.17)	(0.10)	(0.12)
N	2,339	2,339	2,815	2,815	5,154	5,154

Source:

Notes: The table reports the average difference. The scores have been normalized with respect to the distribution of the control group, therefore, the mean of the control group is 0. The standard errors (in brackets) are grouped at the school level. All models include strata fixed effects *, **, *** indicate that the coefficients are statistically significant at a confidence level of 0.10, 0.05 and 0.01 respectively. The perception index is constructed as an average of the teachers' responses to a series of questions about their perceptions about the teaching of mathematics (each with five categories ranging from strongly disagree to strongly agree). This value is then standardized to the mean of the control group. Higher index values indicate a positive perception of mathematics teaching.

Table 6. Impact of JADENKÄ (ITT effect) according to characteristics of student's tutor

	Without controls		With controls	
	Mathematics	Ethno-mathematics	Mathematics	Ethno-mathematics
Panel A. Education level of students' tutor				
Treatment	0.21*	0.17	0.11	0.15
	(0.11)	(0.13)	(0.10)	(0.13)
Without complete primary education	0.25**	-0.09	0.06	-0.08
	(0.10)	(0.11)	(0.09)	(0.10)
Treatment x Without complete primary education	-0.09	0.03	0.03	0.03
	(0.12)	(0.14)	(0.10)	(0.13)
N	1,407	1,407	1,407	1,407
Panel B. Language of the student's tutor at home				
Treatment	0.16	0.00	0.07	-0.01
	(0.10)	(0.12)	(0.08)	(0.12)
Ngäbere	-0.27***	-0.05	-0.17**	-0.07
	(0.10)	(0.11)	(0.08)	(0.11)
Treatment x Ngäbere	0.01	0.33**	0.13	0.32**
	(0.13)	(0.15)	(0.10)	(0.15)
N	1,425	1,425	1,425	1,425
Panel C. The student's tutor is from the comarca				
Treatment	0.22	0.32*	0.08	0.34*
	(0.18)	(0.17)	(0.14)	(0.17)
Tutor from comarca	-0.23	0.33**	-0.11	0.33**
	(0.17)	(0.15)	(0.13)	(0.15)
Treatment x Tutor from comarca	-0.05	-0.16	0.07	-0.19
	(0.19)	(0.18)	(0.14)	(0.18)
N	1,497	1,497	1,497	1,497

Source:

Notes: The table reports the average difference. The scores have been normalized with respect to the distribution of the control group, therefore, the mean of the control group is 0. The standard errors (in brackets) are grouped at the school level. All models include strata fixed effects *, **, *** indicate that the coefficients are statistically significant at a confidence level of 0.10, 0.05 and 0.01 respectively. Ngäbere includes students whose tutor speaks to them in Ngäbere or in Ngäbere and Spanish alike. The reference category is students whose tutor speaks mainly in Spanish.

Table 7. Impact of JADENKÄ on secondary outcomes, 2018, 2019 and both years

	2018						2019			Both years		
	Spanish	Ngäbere	Identity	Spanish	Ngäbere	Identity	Spanish	Ngäbere	Identity	Spanish	Ngäbere	Identity
Intention to Treat Effect (ITT)	0.00	-0.01	0.16***	-0.02	-0.01	0.14**	0.07	-0.03	0.12**	0.04	-0.02	0.14***
	(0.05)	(0.06)	(0.06)	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)	(0.04)
Observations	2,518	2,518	2,518	2,518	2,518	2,518	3,246	3,246	3,246	5,764	5,764	5,764
Per-audio Effect (TOT)	0.000	-0.000	0.006***	-0.000	-0.000	0.006***	0.002	-0.002	0.005***	0.001	-0.001	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
Observations	2,216	2,216	2,216	2,216	2,216	2,216	2,699	2,699	2,699	4,915	4,915	4,915
Intention to Treat Effect (ITT)	0.01	-0.01	0.17***	-0.01	0.00	0.15***	0.07	-0.05	0.17***	0.04	-0.03	0.17***
with TOT sample	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.05)	(0.06)	(0.05)	(0.04)	(0.05)	(0.04)
Observations	2,216	2,216	2,216	2,216	2,216	2,216	2,699	2,699	2,699	4,915	4,915	4,915
Mean of implemented audios	26.4	26.4	26.4	26.4	26.4	26.4	33.6	33.6	33.6	30.3	30.3	30.3
Controls	No	No	No	Baseline	Baseline	Baseline	No	No	No	No	No	No

Source:

Notes: The table reports the average difference. The scores have been normalized with respect to the distribution of the control group, therefore, the mean of the control group is 0. The standard errors (in brackets) are grouped at the school level. All models include strata fixed effects. The number of observations is lower for the TOT estimate because not all teachers report the information about the last audio implemented. Asterisks *, **, *** indicate that the coefficients are statistically significant at a confidence level of 0.10, 0.05, and 0.01 respectively.

Table 8. Impact of JADENKÄ on teachers

	2018	2019	Both years
Number of hours of mathematics per week	-0.33	-0.14	-0.22
	(0.26)	(0.25)	(0.19)
N	423	496	919
Perception about mathematics	-0.06	0.01	-0.02
	(0.10)	(0.10)	(0.08)
N	479	534	1,013
Perception about ethnomathematics	0.05	-	-
	(0.05)	-	-
N	418	-	-
Knowledge about Ngäbe culture	0.56***	0.72***	0.64***
	(0.10)	(0.11)	(0.08)
N	547	523	1,070
Knowledge about Ngäbere words	0.56***	0.69***	0.62***
	(0.10)	(0.11)	(0.09)
N	547	524	1,071
Ethnomathematics	0.56***	0.67***	0.61***
	(0.10)	(0.10)	(0.08)
N	547	524	1,071
Knowledge about Ngäbe objects	0.14	0.11	0.13*
	(0.10)	(0.09)	(0.07)
N	547	535	1,082

Source:

Notes: The table reports the average difference. *, **, *** indicate that the coefficients are statistically significant different from zero at a confidence level of 0.10, 0.05 and 0.01 respectively. All models include strata fixed effects. All the variables, except number of hours of mathematics and ethnomathematics have been normalized with respect to the distribution of the control group, therefore, the mean of the control group is 0. The standard errors (in brackets) are grouped at the school level.

Annex

Annex 1. Example of JADENKÄ Post Audio Activity to Practice the Ngäbe Classifiers for Number of People

Materials: chalk, photos/drawings of people in traditional Ngäbe clothing, numeral worksheets

Teaching sequence: The teacher reviews the counting that the class has practiced in previous lessons. In this lesson, instead of classifiers for round objects, they will use classifiers for people. The teacher shows photos of children and adults. Photo by photo the teacher slowly counts the people in each photo in Spanish and Ngäbere: one person, *itdi*; two people *nibu*; three people *nimä*; four people, *nibogo*; five people, *nirige*.

The teacher draws numerals and rows with chalk on the floor. The teacher says a number in Ngäbere asking that the number of children that corresponds to that number step forward to stand in the corresponding row. For example, when the teacher says *nimä*, the students will organize and agree on how many of them should step forward. In case the students do not reach the correct conclusion, it is an opportunity for the teacher to tactfully initiate a conversation about their thinking and guide them to the correct conclusion. The teacher repeats the activity until the students appear to gain some mastery.

Once the students appear ready for change in activity, the teacher organizes the students in groups of a maximum of four students, instructing them to use the worksheet with numerals to pair photos of people with the corresponding numeral, while saying the numbers in Ngäbere and Spanish. The teacher circulates among the groups to provide guidance.

Formative Assessment:

Does the student know to match a photo of up to five people with the corresponding numeral?

Can the student use the person classifiers to state numbers of up to five people in Ngäbere?

Vocabulary:

idi = one person

nibu = ni = people; bu = two (two people)

nimä = three people

nibogo = four people

nirige = five people