Barriers to Student Success in Madagascar

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ABSTRACT

Various indicators suggest that math and science students in many developing countries are lagging behind their counterparts in other nations. Using Madagascar as a case study, we aimed to: (1) evaluate the effectiveness of education among those enrolled in science and math programs at primary, secondary, and university institutions; and, (2) understand barriers to student progression through the education system. To that end we conducted 63 semi-structured interviews in June and August 2012 with science and math teachers in five population centers, across all three levels of both public and private school systems. We found that crowded classes, limited resources (pedagogical and infrastructural), an average student range in age of seven years per classroom (suggestive of grade repetition and/or late school starting age), and discontinuities in the language of instruction explain why teachers estimated that almost 25 percent of their students would not finish school. Although most secondary and university teachers taught the sciences only in French, they estimated that just one-third of students could fully understand the language. There were also urban-rural and public-private disparities. Teachers in urban areas were significantly more likely to teach using French than their rural counterparts, while public schools also housed significantly larger classes than private institutions. While resource equalization will help to resolve many of these disparities, improved early training in French and increased local autonomy in designing appropriate curricula will be necessary to tackle other shortfalls.

Keywords

international education; school policy; development; literacy; class size; Africa.

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Introduction

There is evidence of numerous social and economic benefits that stem from educating a population (for example: lowered crime, Glewwe, Hanushek, Humpage, & Ravina, 2011; ; improved health and fertility reduction, Kremer & Holla, 2009; democracy and strengthened institutions, Kremer & Holla, 2009; economic growth, Gylfason, 2001; technological advancement, Kremer & Holla, 2009; heightened worker productivity and income, Manacorda et al., 2005). The health-related benefits of education have been particularly well-documented. For instance, the median age of first childbirth rose in accordance with the proportion of young people attending secondary school in developing countries between 1980 and 1995 (Arnett, 2000; Noble, Cover, & Yanagishita, 1996). Furthermore, the Demographic and Health Surveys Program (DHS), which collects nationally representative household survey data in over 90 countries, found a 24 percent reduction in child mortality among women with primary-level education compared to those with no schooling (Pritchett, 2001). Nations that invest in education also tend to experience increases in import penetration and foreign direct investment (Manacorda, Sanchez-Paramo, & Schady, 2005). Accordingly, Hanushek and Woessmann (2008) found a strong positive relationship between nation-specific international achievement test scores and economic growth.

To reap the benefits of educational attainment, some countries – especially those in sub-Saharan Africa – have made extensive efforts to increase enrolment, especially in primary school. These endeavors have led to some notable successes. For instance, 57 percent of appropriately aged children started primary school in sub-Saharan Africa in 2010 (Easton, 2014; UNESCO, 2012), a substantial increase from 1960, when just one in four children went to school (Gulati, 2008; UNESCO, 1993). Nonetheless, some sub-Saharan African countries that have invested heavily in schooling continue to experience slow economic growth and development (Hanushek, 2013; Oyelere, 2007). For instance, the inflation-adjusted gross national product per capita was no higher in Nigeria in 2000 than in 1960 (Gylfason, 2001; World Bank, 2000). One explanation for this is that education systems in some countries are ineffective, and thus students gain few skills by attending school (Oyelere, 2007; Pritchett, 2004; Sanchez et al., 2012).

Recent evidence from international assessments in math and science (Hanushek, 2013) suggests that children in many developing countries are lagging behind their counterparts in other nations. Despite increased enrolment, students in very low-income countries (e.g., many in southern Asia and sub-Saharan Africa) tend to perform badly on standardized tests and thus are held back in school and/or drop out earlier than their counterparts in developed nations (Glewwe & Kremer, 2006; Glewwe et al., 2011). For example, in 1999, grade-eight South African students scored half as well on Third International Mathematics and Science Study (TIMSS) tests as South Korean students (Glewwe & Kremer, 2006). Such clear disparities in educational achievement between countries have often been overlooked during the development of school policy. For instance, the Millennium Development Goal (MDG) for universal primary education (Sanchez et al., 2012; World Bank, 2012) – a high-profile strategy introduced by the United Nations in 2000 to orient development efforts to reduce poverty, disease, and illiteracy in countries across the globe– focused on enrolment, not educational quality (Agrawal, 2014; Hulme, 2007; United Nations, 2012).

A number of factors that influence academic achievement and could explain the poor performance of children in developing countries have been identified. These include

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an assortment of school, class, teacher, student, and community characteristics (Glewwe & Kremer, 2006; Pangeni, 2014; Urquiola, 2003). For example, if teachers struggle to convey basic information effectively to larger groups of pupils (Glewwe et al., 2011), this may negatively affect student performance, especially if the classrooms experience more disruptions due to their large size (Breton, 2014; Glewwe et al., 2011; Pangeni, 2014). Efforts to reduce class size and increase pedagogical resources are among the more prominent initiatives to improve education. Student learning increased in rural Bolivia when class size was kept below 35 students, suggesting that limiting class sizes may be a worthwhile investment (Urquolia, 2003). Nonetheless, high student-teacher ratios are commonplace in developing countries, where government expenditure on education is often low, which results in limited funds for infrastructure (school buildings) and sufficient numbers of trained teachers (Glewwe et al., 2011; Gulati, 2008). Furthermore, students from poor rural communities often cannot afford learning materials that have been shown to enhance student achievement (Glewwe & Kremer, 2006), yet may not be available in under-resourced schools. The rapid expansion of the education system due to increased enrolment has placed additional strain on educational resources (Agrawal, 2014; Glewwe & Kremer, 2006; Pangeni, 2014). Finally, low-quality education may be self-reinforcing, as students who do not learn are often forced to repeat grades (Manacorda, 2012), thus further increasing student-teacher ratios and stretching available pedagogical resources.

For various reasons, students in rural schools in developing countries are at a disadvantage when compared to their urban counterparts. Governments in developing countries typically invest more heavily in urban educational institutions where the potential returns are higher (in Bolivia, Urquiola, 2003; and Nepal, Agrawal, 2014). In addition, fewer teachers and under-qualified teachers with little subject-specific knowledge and/or few years of experience are often assigned to rural schools (Glewwe & Kremer, 2006; Urquiola, 2003). Assignment of under-qualified, inexperienced teachers reduces public expenditures because qualified teachers, many of whom are from urban centers, frequently require additional financial incentives to mitigate the social costs of remote living (McEwan, 1999, for example, distance from family and difficulty finding a spouse; Glewwe & Kremer, 2006; McEwan, 1999; Urquiola, 2003). Experienced teachers may also have sufficient seniority to request transfers to wealthier, urban areas and schools which they view as more desirable places to live and teach (Spaull, 2012). These decisions compromise the quality of rural instruction and thus negatively affect student achievement, often resulting in high dropout and repetition rates in rural schools (Glewwe & Kremer, 2006; Pangeni, 2014).

An additional challenge for students in many developing countries is that they are taught using colonial languages, which are often different from students' mother tongues (Bolivia, Uroquolia, 2009; sub-Saharan Africa, including Madagascar, Glewwe & Kremer, 2006; Dahl, 2011; Glewwe & Kremer, 2009). The need to learn a second language in addition to learning the content of a course contributes to the disparity in the percentage of children who complete school compared with those who enroll (Dahl, 2011; Glewwe & Kremer, 2009). The need for students to learn a second language in school is more pronounced in poorer, remote locations (Brock-Utne, 2001; Kremer & Holla, 2009) where inhabitants speak using local dialects and do not have adequate opportunities to learn colonial languages (Dahl, 2011; Uroquolia, 2009).

Such findings have led many authors (Breton, 2014; Hovens, 2002; McEwan, 1999; Urquiola, 2003) to recommend several key steps – decreasing class sizes, increasing resources available to schools, investing in rural schools, and improving efforts to support students whose native tongue is different from the language of instruction – as means to improve educational outcomes in developing countries. However, support for these steps is not universal, and research to date has revealed mixed (and sometimes conflicting) findings (Breton, 2014; Pangeni, 2014). For instance, after a review of educational studies in developing countries, Glewwe et al. (2011) concluded that class size has no effect on student achievement. In fact, students in larger classes often perform better, although this may simply be a result of greater enrolment in schools where student achievement is higher (Glewwe et al., 2011). In addition, although more learning materials enhance student achievement, the relative importance of different types of resources (pedagogical or infrastructural) on student retention (and ultimately years of schooling) varies by location and student gender (Glewwe at al., 2011). This complicates designing effective and cost-efficient school policies. Furthermore, while rural schools often underperform relative to urban institutions, this may result in part from parental response to perceived quality gaps. Specifically, students who perform well academically are often sent by their parents to live in locations where schools are perceived to be better. Although this behaviour may benefit the student, it could also decrease average student performance in rural schools, thereby reinforcing perceptions of poor school quality. Thus, the best policy options to improve student learning under different social, institutional, and geographical scenarios are complex and not yet fully understood.

Using Madagascar – one example of a country facing challenges as it struggles to improve science and math education – as a case study, we sought to improve understanding of the hurdles students face as they progress through the education system; and, we develop suggestions to mitigate these hurdles. It is likely that the information learned through studying the Malagasy education system can be used to understand similar problems in other sub-Saharan African countries (and, potentially, developing nations elsewhere), especially those which are ex-colonial. Specifically, we aimed to (1) evaluate the effectiveness of science and math education among students enrolled in primary, secondary, and university institutions; and, (2) understand barriers to student progression through school. We focused on rural-urban and public-private differences in class size, age range of students, teacher training and experience, French language comprehension, and available resources as factors that may affect the quality of instruction and therefore inhibit student success. We focused on science and math, as they are subjects that are tested nationally and are often regarded as helpful to students' educational prospects. Success in these topics is also important nationally, as the skills they support are necessary for industry, academics, and governance.

On the basis of past literature on education in developing countries as a whole, along with the low aggregate indicators for educational performance in Madagascar relative to other countries (UNDP, 2013), we expected to find that: (1) large class sizes would be prevalent across all types of educational facilities; (2) high rates of student grade repetition would be prevalent among all classes; (3) teachers of math and the sciences would often have limited qualifications in these subjects; (4) low levels of comprehension of the language of instruction among students would be cited as a key factor affecting their educational advancement; (5) insufficient infrastructural and pedagogical resources would be cited as major barriers to math and science education delivery; and, (6) these hurdles to educational advancement would be more prevalent in public than private schools, and in rural compared to urban locations.

Methods

Malagasy Education System

Madagascar has a population of 21.9 million, 33.2 percent of which is concentrated in urban areas (UNDP, 2013). The median age is 18.2 years, and a large proportion of the populace consists of school age children (UNDP, 2013). In addition, 92 percent of people in Madagascar live on less than 2.00 USD per day

(Schwitzer et al., 2014). Despite widespread poverty, the proportion of appropriately aged children entering the education system in Madagascar is increasing; the net intake rate of the official school age population to grade one of primary school was 63.78 percent in 2003, but rose to 82.48 percent in 2008 (World Bank, 2012). This could partially be due to the elimination of fees associated with attending public primary school in Madagascar in 2002 (World Bank, 2008)[1] The government has also undergone reforms that involve hiring a large number of contract and temporary teaching staff (Glewwe & Maiga, 2011). Despite these recent improvements to educational policy, several indicators suggest that many children are not learning effectively in school. For instance: (1) in 2009, over one fifth of primary school students repeated grades, and only about one third (35.38 percent of females and 33.80 percent of males) persisted to the final grade (World Bank, 2012; UNDP, 2013); (2) only 64 percent of the population aged 15 and up is considered literate (UNESCO Institute for Statistics, 2009); (3) students have persistently low test scores (Glewwe & Maiga, 2011); (4) many students do not pass key exams and therefore do not matriculate into secondary school, especially in rural locations (Glick et al., 2005); and, (5) only 45.8 percent of the population are satisfied with education quality in Madagascar (UNDP, 2013).

The Malagasy primary and secondary school system covers 12 years of education. Within Madagascar, grade levels are referred to interchangeably by their French and Malagasy names. Standardized tests are taken at the end of the fifth, ninth, and 12th school years (CEPE, BEPC, and *baccalauréat*, respectively). This is shown in **Table 1.**

Year in school	French education system	Malagasy education system
1st	11ème: *Course preparatoire 1*	T1
2nd	10ème: *Course preparatoire 2*	T2
3rd	9ème: *Course elementaire*	T3
4th	8ème: *Course moyen 1*	T4
5th	7ème: *Course moyen 2*	T5
	CEPE *(Certificat d'etudes primaires èlèmentaires)*	
6th	6ème	-
7th	5ème	-
8th	4ème	-
9th	3ème	-
	BEPC *(Brevet d'Etudes du Premier Cycle)*	
10th	2nde	-
11th	1ère	-
12th	Terminal year	-
	A: literature major	
	D: sciences and languages major	
	C: mathematics and physics majors	
	Baccalauréat	

Table 1: The Malagasy primary and secondary school system

The Malagasy primary and secondary school system covers 12 years of education, with students generally starting school at the age of five. . Hereafter, for simplicity, we refer to grade level by year, i.e., the first year of school would be the first grade, as opposed to using the French or Malagasy nomenclature.

In Madagascar's public school system, there is one test at the end of each trimester. In order to progress to the next grade level, a student must: (1) pass at least one of the tests; and (2) achieve an end-of-year grade (calculated by the combined scores of all three assessments) that exceeds a given threshold. In addition to these assessments, students face nationwide standardized exams at the end of the fifth, ninth, and 12th school years; they must pass these exams to progress to middle school, high school, or to graduate from high school, respectively (Table 1). Although primary school teachers are permitted to instruct using Malagasy language, the government requires that French be the main language of instruction in secondary and university-level institutions (Brock-Utne, 2001; Dahl, 2011). All students enrolled in university courses must pass a French language test after their first year of instruction.

Social Surveys

We conducted semi-structured interviews (Rietbergen-McCracken & Narayan, 1998) with primary, secondary, and university science and math teachers in five population centers of northern Madagascar (Figure 1; Table 2) from June 29 until August 11, 2012. The sampling locations (settlements positioned along the Route National 6 road, which runs south from Antsiranana) were chosen to represent an urban-rural gradient from a city of 87,569 (Antsiranana) to a village of 500 (Mahamasina; Table 2). Population estimates, the number and type of school institutions present, and the number of teachers interviewed were recorded for each settlement. We attempted to interview at least two teachers per institution, while also maximizing the number of establishments from which the sample was drawn. All interview materials were reviewed and approved by the Temple University Institutional Review Board (Protocol Number 20644, May 2012), and we secured permission from school directors to conduct research at all K-12 institutions prior to the onset of data collection.

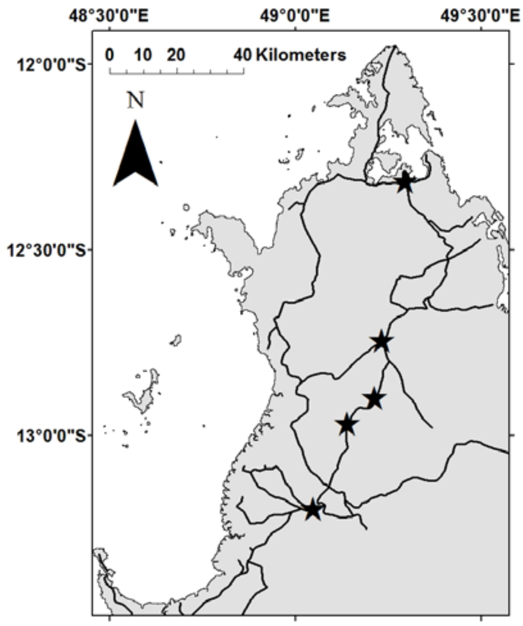

Figure 1: Map of northern Madagascar, where the research was conducted. The locations of the five survey towns are indicated using stars. Roads are depicted with black lines.

Teachers were approached in their workplaces, where they were introduced to the study using face-to-face recruitment. Interviews were scheduled with teachers if they: (1) agreed to participate in the research; (2) taught math or science as a subject; and, (3) were over the age of legal consent (18-plus years). Respondents chose their preferred interview times and locations, along with the language (French or the local Malagasy dialect) in which the questions were

Population center	Human population	Number of teachers interviewed	Public primary schools	Private primary schools	Public secondary schools	University/ technical schools
Antsiranana	87,569	36	6	7	7	2
Ambilobe[a]	56,427	8	ND	ND	ND	0
Aniverano Nord[a]	15,000	9	2	3	1	0
Ambondromifehy	2,500	9	2	2	1	0
Mahamasina	500	1[b]	1	0	0	0

Table 2: Population estimates for our study sites.[2]
[a]Researchers visited two public secondary schools in Ambilobe and only one of the two public primary schools in Aniverano Nord.
[b]Only one teacher was present in Mahamasina.

administered. Interviews were conducted after written consent was obtained by two field staff (one American researcher and one Malagasy translator).

Population estimates for our study sites, are shown in **Table 2**. Estimates are based either on published data or on estimates given to us by the elected president of the local town or village. The number of public/private primary, secondary, and university institutions in each population center, as reported to us by locally elected officials, is also indicated. We conducted teacher interviews in every institution, except where noted otherwise. “ND” stands for “No Data.”

During the interview, respondents were asked about their own qualifications and training, as well as the hurdles they, their colleagues, and students faced in the education system (the survey instrument is in the supplementary materials). We asked each teacher to indicate the age range of students in his or her classroom and used this value as a proxy to quantify rates of grade repetition. Teachers could not provide accurate age-range data for previous years, which meant that we were unable to calculate variability at the respondent level, and therefore used standard deviations as a measure of variance in the data. Given the trade-off between data accuracy and statistical relevance, we chose to analyze the age range of students because it: (1) was easily and accurately reported by teachers; and, (2) it allowed for comparison between individual respondents, instead of requiring us to aggregate data at the school or town level.

We also obtained information relating to additional characteristics (gender, language of instruction) of the interviewed teachers to better understand the structure of the school system. In instances where it appeared that a teacher misunderstood the intent of a question, clarity was provided while refraining from asking leading questions. Respondents were also probed on their responses and encouraged to discuss topics that were important to them. As such, data collected during the standardized interviews were supplemented by information gained through these informal conversations.

Data Analysis

Percentages and means with standard deviations were generated to summarize the demographic characteristics of the sample, as well as to characterize institutional and classroom-level student-teacher ratios; the age range of students in each classroom; teacher

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qualifications, and on-the-job experience; the most common language of instruction used by teachers; the percentage of students estimated to be fluent in French; and the percentage of students estimated to progress to the next grade level[3]. The data did not conform to the assumptions (normality and homogeneity of variance) of parametric tests. Therefore, non-parametric tests were used to identify differences between: (1) primary, secondary, and university institutions; (2) public or private schools; and, (3) sampling locations. Pearson's Chi-squared tests were used to analyze variation in the primary language of instruction most commonly used by science and math teachers operating at different academic stages, types of institution (public or private), and sampling locations. The test was also used to determine differences in the gender distribution of teachers employed in public and private institutions, and at different academic stages.

Kruskal-Wallis Rank Sums tests (a non-parametric test equivalent to ANOVA) were used to analyze the change of quantitative values between data with three or more categories. Specifically, the test was used to substantiate differences between academic stages in respect to the: (1) teachers' qualifications and experience; (2) percentage of students estimated to be fluent in French; (3) average age range of students per classroom; and (4) percentage of students estimated to progress through to the next grade level. In addition, Kruskal-Wallis Rank Sums tests were used to examine how sampling location (town) was associated with: (1) teachers' on-the-job experience; and (2) the percentage of students estimated to be fluent in French. In cases where Kruskal-Wallis Rank Sums tests were significant, a post-hoc test, the Steel-Dwass Multiple Comparisons test, was used to determine where differences between groups were apparent.

Wilcoxon tests (a nonparametric equivalent of a t-test) were used to verify differences between public and private institutions in respect to class size, teacher experience, and the percentage of students estimated to be fluent in French. The test was also used to determine if teacher experience differed between sampling locations.

Finally, when both the independent and dependent variables were quantitative and continuous, significance between the variables was examined using a simple linear regression. A simple linear regression was used to examine whether the number of students and teachers as well as the subsequent student-teacher ratio in each institution was a function of the population of the town in which it was located. A simple linear regression was also used to substantiate whether variations in the size of classes taught by teachers were a function of the academic stage in which they were operating. Values of human population and class size were natural log-transformed prior to the analysis so that the data would meet the assumptions of parametric tests (normality and homogeneity of variance).

Results

We completed 64 interviews: 25 teachers at the primary level, in all five population centers; 28 at the secondary level, including middle school and high school, in all population centers except Mahamasina; and, 11 university educators in Antsiranana (Table 2). The gender of teachers interviewed shifted significantly from primary to secondary school (Pearson's Chi-squared test: X^2 = 8.54, p = 0.013), with females comprising 93 percent and 50 percent of the sample, respectively. The interviews lasted a mean of 14 ± 2 minutes (range: 7 – 75). Three teachers in Antsiranana refused to participate, and nobody ended an interview prematurely. In a few cases, as noted in the individual results below, not all respondents were asked the full set of questions.

Classroom Size and Age Range of Students

On average, teachers instructed science and math classes containing 68.36 ± 52.71 pupils (range: 8 – 256, n = 84); this number increased significantly with the level of the course (simple linear regression: $F_{2,70}$ =

13.9544, $p < 0.0001$, $R^2 = 0.19834$, n = 71). However, after excluding university classes, which were typically large (169 ± 58 students, n = 13), the number of students in K-12 classrooms did not change with the level of the course (simple linear regression: $F_{1,57} = 1.0531$, $p = 0.3092$, $R^2 = 0.019$, n = 58).

The mean age range of students per class was 6.95 ± 2.73) years (range: 2 – 12, n = 61; Table 1. This increased significantly with the level of schooling (i.e. primary [5.73 ± 2.04 years, n = 23], secondary [6.36 ± 2.22 years, n = 24], or university [10.18 ± 1.89 years, n = 11]; Kruskal-Wallis Rank Sums test: X^2: 19.32, $p < 0.0001$). University-level classrooms contained a more diverse age range of students than both primary and secondary ones (Steel-Dwass Multiple Comparisons test: p = 0.0001 and p = 0.0005, respectively). Primary and secondary school classrooms did not differ from each other in this respect (Steel-Dwass Multiple Comparisons test, p = 0.6930).

Teacher Qualifications and Experience

We recorded educational qualifications for 79.69 percent of the 64 science and math educators interviewed(n = 51; in Antsiranana, Aniverano, and Ambondromifehy). The average primary school teacher had not graduated from secondary school. Primary school teachers (n = 19) had received 10.94 ± 1.68 years of schooling. This increased to 14.33 ± 3.69 years, equivalent to two years of university education, among secondary educators (n = 18). University-level teaching staff had the equivalent of eight years of university education, 20.00 ± 0.00 years (n = 11). These differences were significant between primary and secondary school teachers (Steel-Dwass Multiple Comparisons test, p = 0.0048), primary school and university teachers (Steel-Dwass Multiple Comparisons test, $p < 0.0001$), and secondary- and university-level educators (Steel-Dwass Multiple Comparisons test, p = 0.0006).

Teachers had been employed in their current positions for an average of 11.65 ± 8.28 (range: 1 – 33; n = 60) years. This decreased significantly with the level of schooling (Kruskal-Wallis Rank Sums test: $X^2 = 6.7130$, p = 0.0349), with primary, secondary, and university teachers having operated in their current roles for 14.86 ± 10.03 (n = 22), 9.08 ± 7.94 (n = 26), and 7.80 ± 3.29 (n = 10) years, respectively.

Language of Instruction

We asked 31 (48.44 percent) of the 64 teachers we interviewed, in four of our five study sites (excluding Ambilobe), to identify the languages that they used to teach math or science (Figure 2). Teaching using solely Malagasy language only occurred at the primary school level. Conversely, secondary school and, to a lesser extent, university teachers taught primarily in French, yet clarified using Malagasy when their students did not understand. The proportion of educators choosing to teach in Malagasy, French, or in both languages differed significantly between primary, secondary, and university institutions (Pearson’s Chi-squared test: $X^2 = 10.70$, p = 0.015).

Despite French being the dominant language of instruction at secondary and university levels, teachers estimated that only 30.56 ± 34.36 percent (range: 0 – 100 percent, n = 58) of their students were fluent in the language. In addition, all of the teachers who cited a lack of French comprehension among students as a reason why they would not progress through, or complete, school (16 percent, n = 9 of 55 respondents) taught at the secondary or university level. The percentage of students estimated by their teachers to be fluent in French increased significantly from primary (5.47 ± 12.44 percent, n = 21) to secondary (30.86 ± 27.17 percent, n = 23; Steel-Dwass Multiple Comparisons test: p = 0.0002) school, and again once secondary school students matriculated into university (82.27 ± 20.41 percent, n = 11; Steel-Dwass Multiple Comparisons test: $p < 0.0001$).

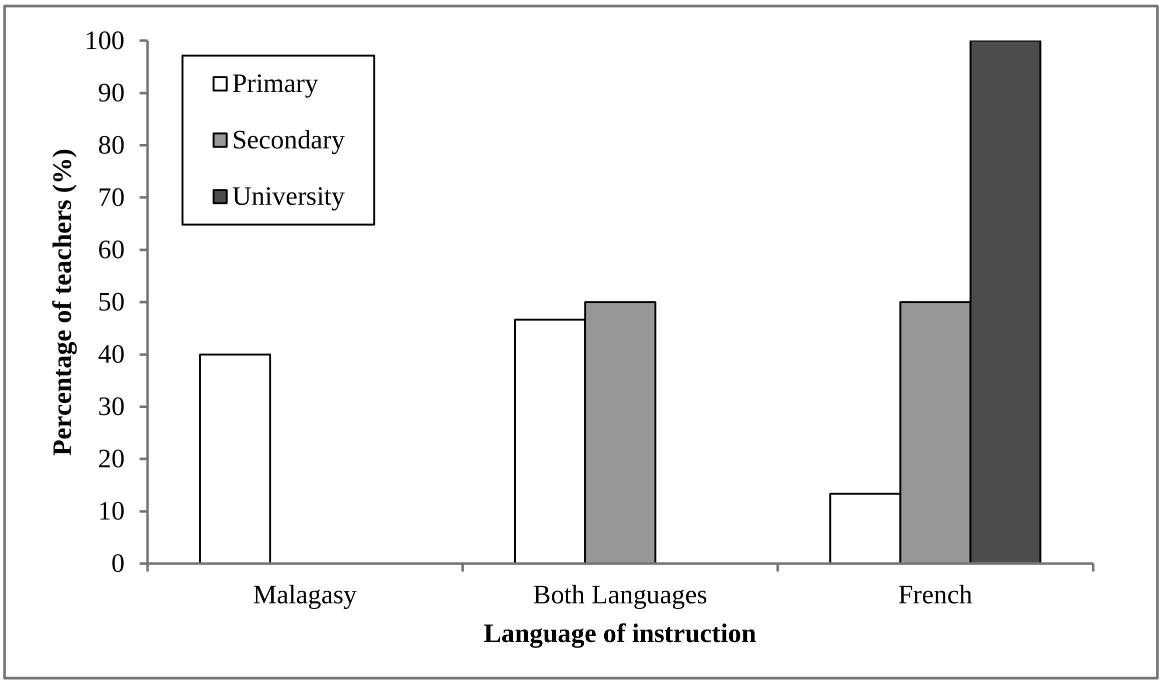

Figure 2: The language of instruction in math and science classes, as cited by teachers of primary, secondary, and university level institutions.

Additional Barriers to Student Progression Through School

Teachers at all levels were asked an open-ended question about any other problems that they felt were impeding their ability to provide effective science and math education to their students. Insufficient school supplies (n = 15) and facilities (n = 12), including the need for a laboratory (n = 11), as well as a shortage of teaching staff (n = 9) and the need for a library (n = 6), were the most common inhibitory factors mentioned. Additionally, five respondents cited insufficient teacher training, student food insecurity, and the absence of a water fountain on school premises as issues. Other respondents stated the need for teachers to help students appreciate education (n = 4), school toilet facilities (n = 3), a French course for students (n = 1), more desks (n = 1), and a security fence (n = 1). University professors also noted that the campus was not safe (n = 1); the library did not have enough books, computers, or Internet access (n = 1); and there was almost no money for faculty research (n = 1).

Teachers estimated that just over three quarters (75.79 ± 21 percent; range: 20 – 100 percent) of their students would choose to enroll in the next grade level upon completion of their respective courses. This did not change significantly between academic stages (primary, secondary, and university; Kruskal-Wallis Rank Sums test: $X^2 = 3.0896$, $p = 0.2134$). Fifty-five teachers gave reasons why students did not progress through, or complete, school. The most common explanations were poverty (38 percent, n = 21), lack of comprehension of the language of instruction (i.e., French; 16 percent, n = 9), and a lack of student knowledge (10 percent, n = 6). Other reasons (as cited by at least three teachers) included teacher absenteeism, student absence, student pregnancy, student psychology (i.e. students believe that they will fail anyway and therefore do not seek higher education), unstable national governance, insufficient school materials, and a lack of parental interest (either in higher education or in the students generally). Every primary and secondary school teacher indicated that, while

	Number of students	Number of teachers	Student body age-range
Primary School			
Antsiranana (n = 5)	451.8 (214 to 863)	8.25 (4 to 12)	11.40 ± 02.07
Aniverano (n = 4)	310 (219 to 521)	9 (6 to 12)	14.33 ± 2.52
Ambondromifehy (n = 4)	349 (220 to 523)	5.5 (4 to 7)	ND
Mahamasina (n = 1)	170	2	15.00 ± 0
Combined Primary and Secondary School			
Antsiranana (n = 5)	531.2 (210 to 1250)	17.2 (5 to 34)	17.00 ± 4.24
Secondary School			
Ambilobe (n = 2)	ND	ND	ND
Antsiranana (n = 2)	940 (363 to 1517)	18	10.00 ± 0
Aniverano (n = 1)	1143	29	14.00 ± 0
University			
Antsiranana Technical School (n = 1)	150	28	ND
University of Antsiranana (n = 1)	3800	ND	ND

Table 3: Mean number of teachers and students at each type of institution at each location.

they prepare students for CEPE and BEPC exams, these are administered only at specific centers to which students must bear the cost of commuting by bus. One teacher cited a fare of 2.50 USD. During informal conversations, teachers explained that student grades on the three other standardized tests which are also used to determine if they should progress to the next grade level tend to increase (n = 9) or decrease (n = 3) throughout the academic year; two respondents explained that student performance could fluctuate during this time. The mean number of teachers and students enrolled in each type of institution in each sampling location is shown in **Table 3**. Not all schools could provide all of the information requested. However, in cases where more than one institution provided estimates, the range of the data is indicated in parentheses alongside the mean values. The mean age range and standard deviation of the student body in each institution, as reported by teachers, is also listed. Finally, the number of schools that provided us with the information is indicated in parentheses alongside the study site name. “ND” indicates that no data were available.

Disparities between urban/rural and public/private institutions

The average number of students and teachers per institution, by educational program, and by location, is summarized in Table 3. Institutional student-teacher ratios in primary and secondary schools did not change with the natural log of the populace of each settlement (Simple Linear Regression: $F_{4,19} = 2.412$, $p = 0.213$, $R^2 = 0.085$, $n = 20$). Public K-12 schools did, however, have significantly larger classes than private institutions (containing a mean of 100.41 ± 66.05, n = 34 and 41.94 ± 24.58, n = 39 students respectively; Wilcoxon test: $X^2 = 19.89$, $p < 0.0001$). They also employed significantly fewer male teaching staff (6 percent and 62 percent of math and science teachers in public and private institutions were male, respectively; Pearson's Chi-squared test: $X^2 = 9.16$, $p = 0.011$).

Primary and secondary school teachers in urban population centers had completed more years of schooling than those in rural ones, though not significantly so (Wilcoxon test: $X^2 = 1.2892$, $p = 0.2562$). For instance, teachers in urban Antsiranana had received 13.14 ± 3.79 years of schooling (range = 8 – 20), compared with those in rural Ambondromifehy, who had completed just 10.33 ± 1.58 years of education (range = 8 – 12). Similarly, private K-12 schoolteachers had completed more education (13.40 ± 3.87 years, range = 0 – 20, n = 15) than their public school counterparts (11.75 ± 2.18 years, range = 8 – 17, n = 16), though this was also not significantly different (Wilcoxon test: $X^2 = 1.1778$, $p = 0.2778$).

The length of teaching career differed significantly between K-12 educators of public (17.11 ± 10.40 years, n = 19) and private (9.44 ± 6.77 years, n = 23) schools (Wilcoxon test: $X^2 = 8.79$, $p = 0.0124$). This did not change significantly between towns (Kruskal-Wallis Rank Sums test: $X^2 = 2.6678$, $p = 0.6149$), though respondents in the most urban study site (Antsiranana) reported the longest teaching careers (12.06 ± 9.63, n = 34).

K-12 private school teachers were less likely than those in public schools to teach in Malagasy (10 percent of private school teachers and 42 percent public school teachers taught using Malagasy; Pearson's Chi-squared test: $X^2 = 3.91$, $p = 0.14$). This is shown in **Figure 3.** The probability of respondents at any educational level using French or Malagasy to address students in the classroom also changed by location (Pearson's Chi-squared test: $X^2 = 22.845$, $p = 0.009$). Additionally, primary school students in urban areas were more likely to be taught the sciences in French; 28 percent of primary school teachers in urban areas (Antsiranana and Ambilobe) reported French as the only language of instruction for the sciences. By contrast, zero percent of primary schools teachers in more rural towns (Ambondromifehy, Aniverano Nord, and Mahamasina) taught the sciences using only the colonial language.

A smaller percentage of public K-12 school attendees were estimated by their teachers to be fluent in French (8.75 ± 17.46 percent, n = 20) as compared to those enrolled in private institutions (19.43 ± 21.91 percent, n = 22; Wilcoxon test: $X^2 = 4.4752$, $p = 0.0344$). Schools in the three largest cities contained the largest percentage of students estimated to be fluent in French (17 percent in Antsiranana, n = 25 respondents; 28 percent in Aniverano Nord, n = 9; and 14 percent in Ambilobe, n = 7). By contrast, just four percent (n = 9) of pupils in the rural village of Ambondromifehy were considered to be fluent in French. These

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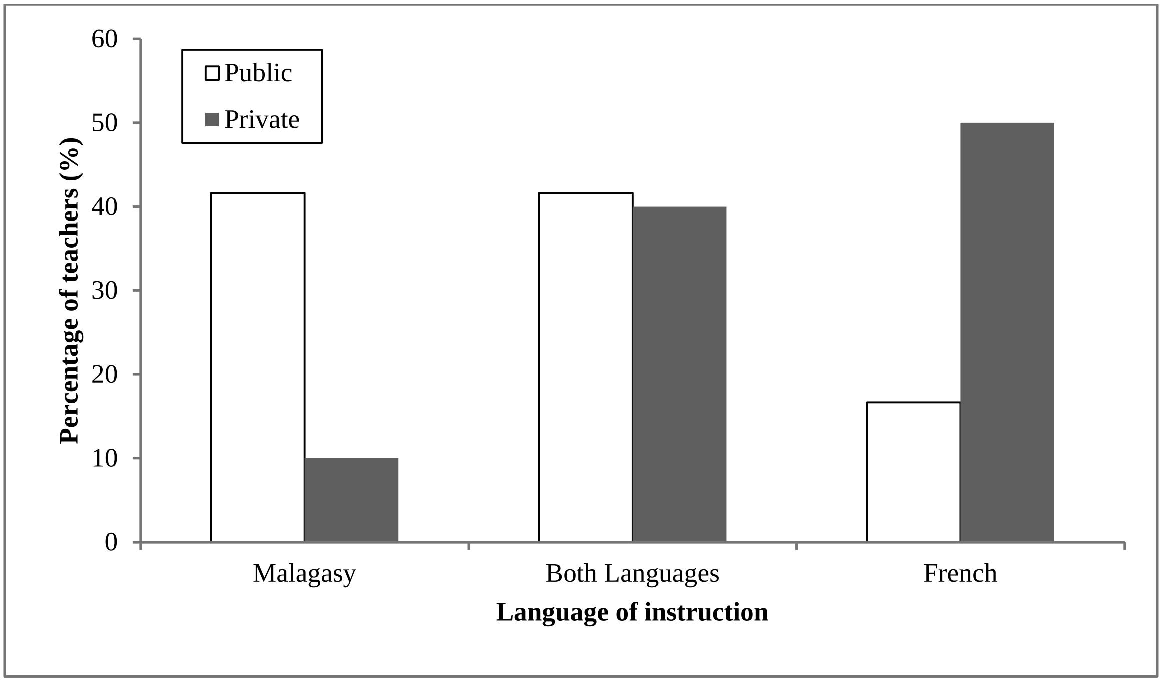

Figure 3: The language of instruction used by K-12 teachers in the public and private school systems in Madagascar.

estimates did not differ significantly (Kruskal-Wallis Ranks Sums test: X^2 = 7.7627, p = 0.0512). The proportion of students estimated to progress to the next grade level (75.79 ± 21 percent; range: 20 – 100 percent) did not change significantly between public and private institutions (Kruskal-Wallis Rank Sums Test: X^2 = 0.3053, P = 0.5806), or by geographic location (Kruskal-Wallis Rank Sums Test: X^2 = 8.6535, P = 0.0704), despite a number of disparities in respect to indicators of educational quality.

Discussion

As we expected, classrooms in the Malagasy education system were typically large. Each pupil, on average, was instructed in classes that numbered more than 67 students. This is a concern given that increasing class size in Colombia from just 20 to 53 students reduced fourth-grade science and math test scores by 16 percent compared to the international average (Breton, 2014). The large class sizes recorded in our study can make teaching more difficult (Breton, 2014). In developing nations, overpopulated classrooms often adversely affect student achievement more than other school characteristics, such as teacher education and experience, or the availability of pedagogical resources (Breton, 2014; Glewwe et al., 2011). Thus, the allocation of additional funds to reduce class size would likely greatly improve educational outcomes in Madagascar and other countries facing the same issue. Nonetheless, reducing class size is expensive (Hattie, 2005), and therefore might not be economical in comparison to other interventions to improve student learning, especially in locations where education funding is low, such as developing countries.

In accordance with our second expectation, the teachers we interviewed often managed classrooms with a large age gap between the youngest and oldest pupil (seven years on average); this difference increased at later grade levels. These results suggest that grade repetition is occurring and/or that some Malagasy children are starting school at a later age than others. In addition, they suggest that grade retention efforts are not working as a means to deter poor student performance in Madagascar. This is supported by the fact that, on average, teachers interviewed in our study estimated that 25 percent of their students would repeat a grade or drop out of school, and thus would not advance to the next grade level. Thus, it is not clear whether the practice of forcing poorly-performing students to repeat grades is a beneficial policy option (Manacorda, 2012). This is because, although the threat of being held back in school can provide a strong immediate incentive for students to do well, it might also result in higher student-teacher ratios and/or increased dropout rates.

Enforcing grade repetition could lead to particularly high dropout rates in areas that lack incentives for students to invest in attaining an education (Handa, 1999), or where there are fewer social pressures on students to continue with school after being held back. This is often the case in poor rural locations. Rural students in developing countries might also underperform, despite trying hard in school, due to factors beyond their control, for example, poverty and/or having limited time for homework because much or all of out-of-school time is devoted to household chores. These problems are likely to be exacerbated by grade repetition because, as children get older, they may be subjected to pressure to contribute to household income (Sabates et al., 2012). Under these circumstances, grade repetition, along with late school-starting age, may be a precursor to non-completion (Sabates et al., 2012). Students might also be deterred from continuing with school by the necessity of paying for transportation to take standardized tests; the 2.50 USD bus fee cited by one teacher in our sample is equivalent to approximately two days of income for 92 percent of Malagasy people (Schwitzer et al., 2014).

Grade repetition might also indirectly lead to poor performance and/or higher dropout rates if students (and/or their parents) become demoralized as a result of being held back in school (Manacorda, 2012). Teachers in our sample noted that some students believed that they would fail and therefore struggled to progress; forcing students to repeat grades is likely to reinforce this mentality. Being held back by one year increased the likelihood that a pupil would drop out of school by 60 percent in Bangladesh (Sabates et al., 2012). Similarly, repeating more than one grade was negatively associated with math performance in poorer primary schools of South Africa (Spaull, 2012). Viable alternative policy options to grade retention exist, with many having been shown to improve student performance in developing countries. For instance, some countries (e.g. Nigeria and the Seychelles) have eliminated grade retention in favor of automatic promotion (UNESCO, 2012). Furthermore, informal and inexpensive remedial education benefitted disadvantaged children in India (Manacorda, 2012). Therefore, automatic promotion, coupled with consistent monitoring of student achievement and additional support mechanisms to prevent them falling behind their classmates, could be effective at reducing dropout rates in developing countries (Sabates et al., 2013).

Consistent with our third expectation, some science and math teachers were under-qualified. The average primary school teacher, in particular, had not completed high school, and presumably faced similar obstacles to learning in school as we documented for the current cohort of Malagasy students. Nonetheless, these Malagasy teachers were more educated than those in some other developing countries. For instance, in northeast Brazil in the 1980s, 60 percent of rural primary school teachers had not even completed primary education (Glewwe & Kremer, 2006). Furthermore, given that the Malagasy primary school teachers in our sample had been employed in education for an average of 14 years – double that of university educators – their lack of formal qualifications could arguably have been mitigated by on-the-job experience. Thus, teachers in Madagascar, on average, had a combined period of training and work experience that was relatively long. Nonetheless, the adequacy of their training and the extent to which on-the-job experience contributed to the quality of instruction they provide remains unclear.

As per our fourth expectation, the teachers we interviewed considered insufficient French language skills among Malagasy students to be a key factor inhibiting educational achievement. Furthermore, respondents at all of our study sites claimed that secondary school and university teachers were not able to speak French well enough to educate students in French, despite being legally required to do so (Brock-Utne, 2001; Dahl, 2011). Current limitations in French language abilities have probably been exacerbated by historical shifts in the official language of primary and secondary education in Madagascar, which changed three times between French and Malagasy from 1896 to 1992 (Dahl, 2011). Similar processes have occurred in other developing countries (e.g. Rwanda; Steflja, 2012). In addition, as noted by one interviewee, math and science classes are taught almost exclusively using French. This may be because pedagogical materials for advanced math and science instruction; as well as Web site content, international journals and conferences; are more readily available in French (relative to Malagasy). Thus, reducing the language barrier by training teachers to communicate effectively in French could increase student success and learning rates in these topics.

In Madagascar, French language skills are considered essential for educational and professional advancement (Dahl, 2011). Such sentiments may arise because French is commonly used as the principal language for communication in many government offices and for other higher-paying jobs. Therefore, knowledge of the language that will be most prevalent in the workplace during a student's later professional career is likely to improve his or her prospects. Opportunities to acquire skills perceived as valuable for professional advancement can also incentivize households to invest in education (Handa, 1999; Harmon et al., 2000). Nonetheless, the difficulties that French language instruction may impose on students – especially students from rural areas, who are often unfamiliar with the language – should be acknowledged.

Students who are taught using a second language may greatly benefit from assistance in learning to understand it effectively. For instance, students (primarily rural children and girls) benefitted from participating in bilingual programmes in Nepal, where classrooms were more stimulating, interactive, and relaxed (Hovens, 2002). Furthermore, pupils in Niger who started learning in their mother tongues could read and write better, even in the second language (Hovens, 2002). These findings suggest that facilitating a gradual transition across grade levels from the use of a local language to that of the professional one may be more effective than complete immersion in the professional language at a certain point during a child's formal education.

Pedagogical materials (e.g. textbooks) can improve student achievement at little cost (Glewwe et al., 2011; Kremer & Holla, 2009). However, consistent with our fifth expectation, several teachers noted that such materials were hard to procure. Infrastructural resource limitations were also frequently problems throughout the school system, and insufficient resources (pedagogical and/or infrastructural) make teachers' jobs more challenging (McEwan, 1999; Sharma et al., 2013). Nonetheless, where resources are lacking, teachers can make student learning more enriching in different ways, both inside and outside the classroom. For example, they could promote cooperative learning by incorporating group assignments into the syllabus (Sharma et al., 2013) and they could replace rote learning with problem-solving exercises. Such innovations should be designed carefully to ensure that they are well-structured and implemented strategically in accordance with local contexts and needs (Sharma et al., 2013). For instance, in rural locations where students and their households are often preoccupied with livelihood-sustaining activities, it will be necessary to assign homework that can fit around or be conducted alongside these responsibilities. Including parents in educational planning may be beneficial as it might enhance parental interest in schooling and their willingness to help their children with homework. In Bangladesh, students who asked for and received help from their parents were nearly 50 percent less likely to drop out than those who asked for but did not receive help (Sabates et al., 2013).

In support of our final expectation, it is likely that public school students had a different educational experience than did those attending private institutions, where there were notably more male employees with less experience. Classes were also smaller in private schools. This could be the direct result of fees associated with attaining a private education (Wietzke, 2011), which may result in classrooms containing primarily wealthier children. This social exclusion is exacerbated in Madagascar, where private institutions tend to occur in wealthier urban settings (Wietzke, 2011). Math and science teachers in the public schools we sampled were less likely to instruct in French, which might be why significantly fewer of their students were estimated to be fluent in French. Despite numerous disparities, the same proportions of students were estimated to progress through public and private schools.

Also as expected, teachers at rural schools in our study faced unique challenges in educating their students. We found that there are fewer incentives for households in remote locations to invest in schooling. This is because rural students often lack local options for secondary or university education (as evident from our dataset, Table 2; Handa, 1999). In addition, a large percentage of the rural labor force in developing countries is engaged in low-skill primary production jobs (Glewwe et al., 2011; Gylfason, 2001; Oyelere, 2007). Furthermore, although we found that science and math classrooms were more crowded in urban settings, the lower student-teacher ratios in rural settings did not necessarily indicate better education in rural areas. This could be because children in rural locations, who typically live in households that are worse off socioeconomically that their urban counterparts, are needed to assist in agricultural tasks and therefore are simply not going to school (Urquiola, 2003).

The teachers we interviewed highlighted financial and food insecurity as reasons why they struggle to educate students effectively. These are common concerns for rural families in developing countries (Hannum et al., 2014), and often result in parents taking students out of school during certain seasons (e.g. during rice harvests) to assist with domestic chores and/or earn income to meet family needs (Glewwe & Kremer, 2006; Glewwe et al., 2011; Pangeni, 2014). This practice could explain why Malagasy teachers in our sample raised student absence as an issue, and why some observed that student performance fluctuated throughout the year. By not attending school, it becomes more difficult for rural inhabitants to find higher-paying jobs and to progress out of poverty (Gylfason, 2001). Nonetheless, certain interventions can counteract pressures to take children out of school to earn money (Glewwe & Kremer, 2006). For instance, the provision of mid-day meals reduced student absenteeism, increased enrolment, and significantly increased the number of years of education completed by students in India

(Dreze & Kingdon, 2001; Agrawal, 2014). However, this might not be an appropriate solution under all circumstances. Glewwe et al. (2011) found that the provision of meals in schools in developing countries positively affected student test scores in just six out of 13 cases. This highlights the need to design interventions that are locally appropriate.

Conclusions and Recommendations

Our study indicates that students in science and math classes in Madagascar – similar to those in other developing countries – are subjected to large class sizes and may be frequently repeating grade levels. Students often also lack the language skills needed to learn course material and advance professionally after completing school. In addition, science and math teachers in Madagascar – while having a relatively extensive combination of formal education and professional experience – may lack advanced training in their subjects, may have inadequate French language skills to teach students in French, and be limited by insufficient access to teaching materials. Finally, educational experiences may differ between private and public schools, and between rural and urban locations, in Madagascar.

Our study indicates that there are at least five aspects of the education system that could be targeted to improve the effectiveness of science and math instruction in Madagascar: (1) classroom size; (2) grade repetition; (3) resource availability; (4) French language skills; and (5) educational disparities. First, reducing class sizes in Madagascar – although it may not be financially feasible for all subjects (Hattie, 2005) – could be especially beneficial for mathematical disciplines (Breton, 2014), or in urban areas where larger classrooms are found. Second, following successful programs in other countries (Manacorda, 2012; Sabates et al., 2013; UNESCO, 2012), grade repetition could be eliminated in favor of automatic promotion supplemented by informal remedial education. Third, increasing the supply of pedagogical materials to schools could also help improve student learning.

Fourth, there are several ways to address the lack of French language skills among students and teachers in Madagascar. To increase student understanding of science and math topics, we suggest either: (1) bilingual science and math education starting in primary school; or (2) facilitating a gradual transition from Malagasy to French throughout the education system, thereby eliminating the sudden language switch that occurs between primary and secondary school. To increase the ability of teachers to communicate in French, we recommend that schools: (a) take steps to enhance existing teachers' skills in the language and place additional weight on French skills as a condition of employment for new hires; and (b) train teachers to facilitate a gradual transition from using native to professional languages across grade levels, while also providing effective math and science education. Rural public schools – where teachers were less likely to instruct in French and students are less likely to be exposed to colonial languages in their day-to-day lives – should not be overlooked when implementing such procedures. Nationwide teacher education programs have been recommended as a means to overcome inequity between rural and urban communities in developing countries in Asia (Sharma, et al., 2013). Resource equalization across schools, such as the P-900 program in Chile, is also likely to reduce rural/urban disparities (Manacorda, 2012). It should be noted that, where formal investment in teacher training is not available, informal interventions – such as discussion groups and workshops – may be cheaper, yet effective, alternatives (Sharma et al., 2013).

Fifth, local or regional interventions could target disparities in educational quality. At present, most developing countries enforce single, centralized curricula (Glewwe & Kremer, 2006). These are beneficial in that they often provide common minimum standards and can be adopted by schools that otherwise lack the resources to develop their own curricula. They are also likely to make it easier for students and teachers to adapt following transfers to new schools. However, given the heterogeneity in educational background, school quality, language, and the external pressures faced by students in different regions, designing single curricula that are appropriate for all students is difficult, if not inappropriate (Glewwe & Kremer, 2006). Thus, we support greater local control of educational systems, which has already been granted in some areas (e.g. in the case of non-formal education centers in India and EDUCO schools in El Salvador; Glewwe & Kremer, 2006). In general, cross-country evidence points towards positive outcomes from devoting resources to local governments to allow for local autonomy and collaboration in educational decision-making (provided that there is an accountability system in place; Glewwe et al., 2011; Sharma et al., 2013). This approach could also lead to – and benefit from – more community participation in the education system.

Finally, we encourage continued education-related data collection efforts across Madagascar; baseline data which could be used to assess and target interventions to improve the quality of science and math education in the country was lacking or outdated. For instance, many teachers and school directors could not provide accurate estimates of enrolment rates at their institutions, while government education officials – in some cases – could not provide us with the number of schools and students in their precincts. These data, along with more detailed information regarding student learning, are needed in order for the Malagasy government and social development agencies to design effective, decentralized support programs to supplement science and math education in the country.

Notes

1. We could not find comparable data on intake rates prior to this date.
2. Population estimates were obtained from: Ilo Program; Recensement des Communes, 2001; Cornell University, 2003. Downloaded on January 13, 2014 from http://www.ilo.cornell.edu/ilo/data.html.
3. Quantitative data were analyzed using JMP® software (Version 10. SAS Institute Inc., Cary, NC, USA).

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The Ladybug Project is a US-based nonprofit organization that has been undertaking small education and healthcare outreach programs in the African countries of Equatorial Guinea and Madagascar since 2010. **The Ladybug Project In**c., 401 W. Dauphin St., Enola, PA, 17025, USA