How to improve teaching practice? Experimental comparison of centralized training and in-classroom coaching

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How to improve teaching practice? Experimental comparison of centralized training and in-classroom coaching.[*]

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Abstract

We experimentally compare two modes of in-service professional development for South African public primary school teachers. In both programs teachers received the same learning material and daily lesson plans, aligned to the official literacy curriculum. Pupils exposed to two years of the program improved their reading proficiency by 0.12 standard deviations if their teachers received centralized *Training*, compared to 0.24 if their teachers received in-class *Coaching*. Classroom observations reveal that teachers were more likely to split pupils into smaller reading groups, which enabled individualized attention and more opportunities to practice reading. Results vary by class size and baseline pupil reading proficiency.

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1 Introduction

In most of the developing world, children are attending school without adequately learning to read. In South Africa, for example, a striking 78 percent of students still cannot read with meaning after four years of schooling (Mullins et al. 2017).[1] Such low levels of reading proficiency have also been documented in South Asia and elsewhere in sub-Saharan Africa (Banerji et al. 2013, Bold et al. 2017). Since reading is a gateway to future learning, addressing these shortcomings should be a policy priority.

Evidence suggests great potential to accelerate learning by improving the quality of teaching, but changing ingrained teaching practices presents a significant change. Numerous studies have found that teachers play a critical role in shaping a child's learning trajectory (Das et al. 2007, Clotfelter et al. 2010, Rivkin et al. 2005, Staiger & Rockoff 2010). And good teaching practices correlate with faster learning (Allen et al. 2013, Araujo et al. 2016). Yet, teacher quality is highly variable, both within and between countries. In recognition of this, government and donors invest billions of dollars annually on in-service teacher professional development,[2] but with disappointing results. For example, many studies in the United States have found no impact of professional development programs on student learning, especially when conducted by government at scale;[3] and a recent meta-analysis of evaluations of in-service teacher training programs in developing countries concluded that "teacher training programs vary enormously, both in their form and their effectiveness" (Popova et al. 2016). One possible reason for the failure is that many programs focus only on imparting knowledge, yet teaching is a skill that needs to be developed through ongoing practice (Kennedy 2016).

Broadly defined, there are two common approaches to in-service teacher professional development: training at a centralized venue, or classroom visits by coaches who observe teaching, provide feedback, and demonstrate correct teaching techniques. The first approach provides more time for a deeper conceptual understanding to develop before actually implementing the new techniques, but it might not be sufficient to change behavior. The second approach could facilitate a change in behavior by encouraging practice, which may in turn lead to learning by doing; and targeted feedback could assure correct application of techniques. There is promising evidence that this approach can succeed at shifting teaching practice and improving student learning (Kraft et al. 2018), but it is generally considered more expensive (Knight 2012). Recent evidence has also shown that low-cost adaptations to coaching, such as using online technology, is less effective (Oreopoulos & Petronijevic 2018).

A possible cost-effective way to encourage adoption of new techniques is the use of scripted lesson plans (Jackson & Makarin 2018), but they are not without controversy. Lesson plans can reduce the cost to teachers of switching to a new technique, and provide daily prompts and reminders to encourage

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[1] This is the percentage of children scoring less than the low international benchmark score, as defined by the Progress in International Reading Study (PIRLS)

[2] By some estimates the United States spends 18 billion annually on teacher professional development (Fryer 2017). According to a nationally representative survey conducted in 38 developed countries, 91 percent of teachers received professional development in the past 12 months (Strizek et al. 2014). And Popova, Evans & Arancibia 2016 calculate that nearly two thirds of World Bank-funded education programs include a professional development component.

[3] Jacob & Lefgren (2004), Harris & Sass (2011), Garet et al. (2011, 2008), Jacob & Lefgren (2004), Randel et al. (2011)

practice. But some are concerned that they could reduce teacher autonomy and thus hinder a good teacher's ability to cater his/her teaching to the needs of the child (Dresser 2012).

Is a short centralized training program —combined with daily lesson plans that prompt and guide the implementation of the new practice— sufficient to ensure use of new practice? How important is ongoing individualised observation and feedback, provided by an expert coaches, for ensuring that new practices are implemented and implemented well? How does this depend on the characteristics of the student, teacher or the class size? Ultimately, which approach —training or coaching— is more cost-effective at improving student learning?

To answer these questions, we conduct a randomized evaluation in 180 public primary schools in South Africa, comparing two different approaches to improving the teaching of home language reading in the early grades. The first approach (which we refer to as *Training*) follows the traditional model commonly employed by governments: short, intensive training held at a central venue.[4] In the second approach (which we refer to as *Coaching*), specialist reading coaches visit the teachers on a monthly basis to observe teaching practice and provide feedback. The average duration of exposure to the programs over the course of the year is roughly equivalent.[5] Both interventions also provide teachers with daily lesson plans and educational materials such as graded reading booklets, flash cards, and posters. The lesson plans are based on official government curriculum and mirror exactly the pedagogical techniques prescribed by government, but at a higher level of specificity. Moreover, the same individuals delivered both training and the coaching, so any differences we observe cannot be due to differences in the quality of implementation. Coaching costs roughly 43 USD per student annually, compared to 31 USD for Training.

We assessed the reading ability of a random sample of 20 students in each school at three points in time: once as they entered grade one prior to the roll-out of the interventions (February 2015), and again at the end of their first and second academic years (November 2016 and 2017 respectively). During these school visits, we also surveyed teachers and the school principal.

We also conducted detailed lesson observations in a stratified random sample of 60 schools in October 2016— 20 schools in each evaluation arm. The lesson observation instrument was explicitly designed to capture the teaching practices prescribed by government and thus targeted by the program.

We find that, after two years of exposure to the program, students' reading proficiency increased by 0.12 and 0.24 standard deviations if their teachers received Training or Coaching respectively. The impacts are larger still —0.18 and 0.29 standard deviations respectively— when we exclude the small sample of multi-grade classrooms, a setting where the program was never intended to work. We conclude that Coaching is more cost-effective than Training with an estimated 0.57 standard deviation increase in reading proficiency per 100 USD spent per student annually, compared to 0.39 in the case of Training.

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[4] In our case, teachers receive two training sessions, once at the beginning and once in the middle of the year, each lasting two days.

[5] We estimate that the average number of hours of exposure to the programs were 32 and 37 hours for the Training and Coaching arms respectively. So, roughly 4/5 days in total.

Next, our classroom observation allows us to unpack mechanisms by measuring how teaching practice changed in the classrooms. We find that even though there is no change in the frequency that the students are practicing reading in the classroom, there is a big change in *how* they practice reading: teachers in both treatment arms are more likely to implement a technically challenging teaching technique called group-guided reading, where the students read aloud in smaller groups. As a result, students are more likely to receive individual attention from the teacher when they read, and more students are also using the graded reading booklets. The largest improvement is consistently observed in classrooms where the teachers received Coaching. Notably, we see no change in other activities that are also required to take place at a daily basis, but are easier to teach.[6] We perform mediation analysis, following Acharya et al. (2016), and conclude that more than half of the impact of Coaching can be explained by the improvements in group-guided reading.

Taken together, our results show that a combination of training and lesson plans can shift teaching practice and improve learning, but the shift is far larger when teachers receive ongoing observation and feedback from a coach, especially for the more difficult techniques.

Our paper contributes to growing evidence from developing countries demonstrating that a bundled intervention of training, lesson plans, and coaching can dramatically improve students' proficiency in early-grade reading (Piper et al. 2014, 2018, Lucas et al. 2014, Kerwin et al. 2017). This is also consistent with the conclusion from a recent review that structured pedagogic programs —a combination of highly specified curricula, training on instructional methods, and additional learning materials— have great potential to improve learning (Snilstveit et al. 2016). This paper makes a unique contribution in two important ways. First, we experimentally vary two common forms of teacher professional development: training versus coaching. This allows us to unpack which components are uniquely responsible for the learning gains, and test for the importance of observation and feedback in developing skills. This is important, since one-off training is the most common form of government teacher professional development, yet most research looks at a more resource-intensive model of coaching. Second, the detailed classroom observations, which were explicitly developed to measure the teaching practices emphasized by the program, shed light on the underlying mechanisms.

Results of this study also contribute to debates around teacher autonomy. There is often push-back against a prescribed curriculum and set pedagogical standards, because of the fear that it will undermine teacher autonomy and limit a teacher's ability to cater her teaching to the level of the child. Our study demonstrates the benefits of a structured pedagogical program. Teacher satisfaction with the program was high, underscoring the fact that teachers value the structure provided by standardized lesson plans. There was no detectable negative impact on any segment of the pupil population, so the reduced teacher autonomy does not come at a cost of lower learning for some types of pupils. However, it is concerning here was no detectable positive impact for the weakest students, despite the fact that programs improved the enactment of the national curriculum.

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[6] Phonics and letter recognition are also required to be taught daily and are typically taught through whole-class reading, where all the children in the classroom follow or read with the teacher. This is a far easier form of teaching.

The paper proceeds as follows: section 2 describes the interventions and the motivating theoretical channels, section 3 describes the evaluation design and empirical strategy, section 4 reports results, and section 5 concludes.

2 Program description and theoretical framework

2.1 Program

Working with the South African government, we designed two related interventions aimed at improving early-grade reading in one's home language.[7] Both interventions provide teachers with lesson plans, which describe in detail the content that should be covered and pedagogical techniques that should be applied for each instructional day.[8] In addition, teachers receive supporting materials, such as graded reading booklets, flash cards, and posters. The graded reading booklets provide a key resource for the teacher to use in group-guided reading (discussed in more detail below) so as to facilitate reading practice at an appropriate pace and sequence of progression. The program was led and managed by government, who appointed a service provider, Class Act, to implement the interventions.

The two interventions differ in their approach to improving teacher pedagogical practice. The one intervention trains the teachers on how to use the lesson plans and accompanying materials through central training sessions, each lasting two days and occurring twice yearly (at the beginning of the first and second semester respectively). During these training sessions, roughly a quarter of the training time was meant to be spent on teachers practicing the techniques. The ratio of facilitators to teachers during the training was roughly $7:1$.[9] The trainers also performed follow-up visits to most of the schools, in order to encourage them to continue with the program. We refer to this intervention as Training.

The second intervention, which we refer to as Coaching, provides exactly the same set of instructional materials. However, instead of central training sessions, specialist reading coaches visit the teachers on a monthly basis over the duration of the academic year in order to improve teacher content knowledge, and pedagogical techniques, and professional confidence. During these visits the coaches observe teaching, provide feedback on how to improve, and demonstrate correct teaching techniques. The coaches also hold information session with all the teachers at the start of each term to hand out new materials; and occasionally hold afternoon workshops (one to three a year) with a small cluster of nearby schools that are part of this intervention. There were three coaches, each serving 16-17 schools. The coaches are educated —all three had a at least a bachelors degree— and have past experience as both teachers and coaches. They received additional training from Class Act at the start of every term.[10]

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[7] In South Africa, most children are taught in their home language in grades one to three and then experience a transition to English as the language of instruction in grade four.

[8] Teachers were strongly encouraged to use the lesson plans, but this was not enforced.

[9] Roughly 140 teachers and head teachers participated in the training. Given the large number of teachers participating, two training sessions were conducted per semester with roughly 70 teachers per group. Ten facilitators participated in each of the training sessions.

[10] The training focused on coaching and mentoring, school curriculum, and teaching skills.

The coaches also conducted the training, so the differences between the programs cannot be attributed to the expertise of those administering the programs.

The program was implemented over a period of two years: in the first year all the grade one teachers in the treatment schools received training/coaching, in the second year all grade two teachers in treatment schools received it. Thus, the same cohort of students benefited from the program, but a different set of teachers participated each year. Figure B.1 provides a schematic breakdown of the timeline.

Figure 1 shows the distribution of teacher exposure to the coaching program in 2016, based on data collected by Class Act. We see that the median number of visits that a teacher received was ten, but some teachers received far fewer visits. There was also high variation in the number of afternoon workshops that teachers attended. Putting this all together, we calculate that the average number of hours of exposure to the program was 36.7.[11] According to administrative data, teacher attendance for Training was high —98 and 93 percent for the two sessions held in 2016— and there were a total of 157 follow-up visits. The organization held follow-up training for the teachers who missed the initial training. The average number of hours of exposure to the program is roughly 34.[12]

It is important to note that both treatments follow the same curriculum as in the control. The lesson plans are fully aligned official government curriculum, both in terms of the topics covered and instructional techniques prescribed. The lesson plans are also integrated with the government-provided workbooks, which detail daily exercises to be completed by students.

Any difference we observe is therefore due to the modality of support the teachers receive, not the pedagogical content.

2.2 Theoretical framework

How (not) to teach reading? Despite debates around specific methodologies of teaching literacy, there is general consensus on how students learn to read.[13] Acquisition of reading proficiency requires systematic practice of all the different components of reading at the appropriate sequence and pace: starting from the development of vocabulary, to recognizing sounds and letters (decoding), and moving towards recognizing words and eventually reading extended texts. The ultimate goal of reading with comprehension can only be reached once someone can read fluently— i.e. when reading becomes automatic and requires no conscious effort. This requires continual practice, as well as individual feedback to correct a student if she is reading incorrectly.

In this regard, the South African literacy curriculum is well-aligned with international best practice. It prescribes in detail the frequency with which different teaching activities should take place. For example, group-guided reading —where smaller groups of students read the same text under the direction of the

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[11] Assuming that each information session lasts five hours, each coaching visit lasts one and a half hours (one hour observation and 30 minutes feedback), and each afternoon session lasts two hours.

[12] Assuming that teachers spent on average 20 minutes talking to the teacher when visited by the trainers. The trainers were only supposed to talk to the school principals, but inevitably also talked to the teachers.

[13] See, for example, Langenberg et al. (2000).

teacher— is supposed to take place at a daily basis (Department of Basic Education, 2011).[14] This activity is an important ingredient to learning, since it provides opportunities for students to practice reading and receive individual feedback from their teacher, but it is difficult to implement.

However, in South Africa there is a significant gap between existing practice and what is prescribed in the curriculum (Hoadley 2012). The dominant norms of practice in South Africa involve an over-reliance on teacher-directed strategies and whole-class activities, such as "chorusing", where the teachers and student all read together, or repeat after a teacher. With these activities, there is a risk that students do not attempt to read themselves and merely mimic what the teacher is reading. In the worse possible equilibrium, the students pretend to be reading and the teachers pretend to be teaching. There is also documented evidence of highly incomplete curriculum coverage, and ineffective curriculum sequencing and pacing by teachers (Taylor et al. 2011).[15]

How to change teaching practice? Both interventions of this study are built around the assumption that, just like learning to read, teaching is a skill that needs to be developed through regular practice, and teachers might need additional guidance and support to ensure consistent and correct application of the new techniques. Skill acquisition could lead to a sustained change in behavior, either by increasing the marginal product of effort for intrinsically motivated teachers (who now see the fruits of their labor), or by reducing the marginal cost of effort (once-difficult tasks now become easy to implement).

The lesson plans provide several mechanisms for ensuring that the methods are actually implemented and implemented well. Firstly, the provision of fully scripted lesson plans can reduce the effort cost of transition to a new set of practices, since teachers do not need to develop daily plans themselves. Secondly, even before a teacher has a deep understanding of the methods or curriculum topics, the lesson plans prompt enactment, thus creating the possibility for learning by doing. In this way, the regular routines embedded in the lesson plans foster an iterative relationship between knowing and doing through which the teachers own instructional repertoire is expanded. Lesson plans also provide a way to ensure that new reading materials are used and are integrated into a lesson in a coherent way. Lastly, lesson plans provide a focus for the entire intervention guiding not only the use of time and materials but providing a point of focus for all training or coaching interactions. In these ways, lesson plans can be viewed as providing a set of mechanisms to encourage correct implementation of the curriculum and of what is taught at training sessions.

A significant initial dose of training might be important if a thorough conceptual understanding of new topics and methods is necessary before effective implementation is possible. However, there may be other practical and emotional constraints to introducing a new set of routines and activities into an existing classroom space.

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[14] These groups should ideally be sorted by ability: the teacher is expected assess reading ability by observing each student as she reads a text.

[15] This is possibly because the curriculum has been revised several times in recent decades, but most teachers were not properly trained to implement new methods and did not have all the necessary reading materials.

The coaching intervention, whilst not relying on deep knowledge before implementation, does provide an additional set of mechanisms to ensure that new methods are being attempted (somebody is there to observe thus playing a monitoring role), to facilitate an evaluation of how new practices are being implemented, and to encourage re-implementation in a better way through both guidance and even modelling best practice themselves.

3 Evaluation Design

3.1 Sampling and Random Assignment

The study is set in two districts in the North West Province, in which the main home language is Setswana. This province is relatively homogeneous linguistically and is one of the poorer provinces in South Africa. Our sample is restricted to non-fee public schools schools that use Setswana as the main language of instruction, and were identified as unlikely to practice multi-grade teaching.[16] We randomly drew a sample of 230 schools from this population and created 10 strata of 23 similar schools based on school size, socio-economic status, and previous performance in the the national standardized exam, called the Annual National Assessments (ANA). Within each stratum we then randomly assigned 5 schools to each treatment group and 8 to the control group. All treatment schools with exception of one in the Coaching arm agreed to participate in the program. We included this school in the sample of treatment schools.[17]

We chose to exclude schools that practice multi-grade classes, since the interventions are grade-specific and unlikely to work in such settings, but we were unable to *ex ante* exclude all those schools: roughly 6 per cent of grade two teachers in each treatment arm reported teaching pupils from multiple grades in the same classroom. For sake of transparency we report results on both the full sample and the restricted sample that excludes pupils who were taught in a multi-grade setting.

3.2 Data collection

We visited each school three times: once prior to the start of the interventions (February 2015), again after the first year of implementation (November 2015), and finally at the end of the second year (November 2016). During these school visits we administered four different survey instruments: A pupil test on reading proficiency and aptitude conducted on a random sample of 20 pupils who entered grade one at the start of the study, a school principal questionnaire, a teacher questionnaire, and a parent/guardian questionnaire. We assessed the same pupils in every round of data collection, but surveyed a different set of teachers between midline and endline, because pupils generally have different teachers in different

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[16] Approximately 65% of South African children attend non-fee schools. Schools serving communities with higher socio-economic status are allowed to charge fees, but receive a smaller government subsidy as a consequence.

[17] The full evaluation also consisted of a third treatment arm with a different focus on parental involvement (rather than teacher training), the result of which we will discuss in a separate paper.

grades. Finally, we also conducted lesson observations on a stratified random sub-set of 60 teachers in September 2016. The data-collection and data-capture organizations are independent from the implementing organization and research team, and were blind to the treatment assignment.

We registered a pre-analysis plan at the AEA RCT registry in October 2016, before we had access to the endline data.

3.2.1 Pupil assessment

The pupil test was designed in the spirit of the Early Grade Reading Assessment (EGRA) and was administered orally by a fieldworker to one child at a time. The letter recognition fluency, word recognition fluency and sentence reading components of the test were based on the Setswana EGRA instrument, which had already been developed and validated in South Africa. To this, we also added a phonological awareness component in every round of assessment. The baseline instrument did not include all the same sub-tasks as the midline/endline instruments, because of different levels of reading proficiency expected over a two-year period. For baseline, we also included a picture comprehension (or expressive vocabulary) test since this was expected to be an easier pre-literacy skill testing vocabulary, and thus useful for avoiding a floor effect at the start of grade 1 when many children are not expected to read at all. Similarly, we included a digit span memory test.[18] The logic of including this test of working memory is that it is known to be a strong predictor of learning to read and would thus serve as a good baseline control to improve statistical power. For the midline and endline, we added a writing and a paragraph reading sub-task. For endline, we further added a comprehension test.

Out of the $3,539$ pupils surveyed in baseline, we were able to re-survey $2,951$ in endline, yielding an attrition rate of 16.6 per cent. The attriters had either moved school (90 per cent of attriters) or were absent on the day of assessment (10 per cent of attriters). Moreover, an additional 13% of our original sample were repeating grade one. Figure B.2 shows the breakdown of attrition and repetition by treatment arm. Column (1) in table A.1. regresses treatment assignments on attrition status, after controlling for stratification. It shows there is no statistically significant difference in attrition rates across treatment arms. Columns (2) to (4) regress different student characteristics —student age, gender, and baseline reading proficiency— on treatment status, attrition, and an interaction between attrition and treatment status. Attriters in the control are slightly older and less likely to be female. However, the coefficients on the interaction terms show that there are no differences in the characteristics of the attriters across evaluation arms, with the exception that attriters in the Training arm are slightly more likely to be female, relative to the control. We control for student gender in all our student-level analysis.

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[18] This involved repeating by memory first two numbers, then three, and so forth up to six numbers, and the same 5 items for sequences of words.

3.2.2 Survey data and document inspection

The teacher survey contained questions on basic demographics (education, gender, age, home language), teaching experience, curriculum knowledge, and teaching practice. For curriculum knowledge, we asked the frequencies with which the teacher performs the following activities: group-guided reading, spelling tests, phonics, shared reading, and creative writing. The prescribed frequency of performing these activities is stipulated in the government curriculum and also reflected in the lesson plans. Performing these activities at the appropriate frequency is thus a measure of knowledge and mastery of the curriculum, as well as fidelity to the lesson plans. Note that even if there is risk of social desirability bias, these measures still accurately capture knowledge of the appropriate routines, since some activities are supposed to take place infrequently.[19].

The questions on teaching practice covered important pupil-teacher interactions that flow from group-guided reading: whether teachers ask pupils to read out loud, provide one-on-one assessment, and sort reading groups by ability.

Finally, the teacher survey also included a voluntary comprehension test, which was completed by 75, 89, and 98 per cent of teachers who completed the teacher survey at baseline, midline and endline respectively.

In the endline, we have teacher survey data for 275 teachers in 175 schools. As a result, for 81 percent of the $2,951$ pupils assessed at endline, we also have data on their teacher.[20] In column (5) in Table A.1 we regress treatment assignment dummies on an indicator for whether a pupil's teacher also completed the teacher survey. We see that teacher non-response was random across treatment arms.

We also conducted classroom and document inspection for the surveyed teachers. Fieldworkers counted the number of days that writing exercises were completed in the exercise book, and the number of pages completed in the government workbook.[21] To minimize risk of bias due to strategic selection of exercise and workbooks, the teacher was asked to provide books of one of the most proficient pupils in his/her class. Furthermore, fieldworkers indicated if the teacher has a list for the reading groups—the names of the students as they are assigned to each reading group, and rated on a 4-point Likert scale the sufficiency and quality of the following print material: a reading corner (box library), graded reading booklets, Setswana posters, and flashcards.

The school principal survey includes basic demographic questions, questions on school policies, school location, school access to resources, and a rough estimate of parent characteristics: the language spoken most commonly in the community, and highest overall education of the majority of parents.

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[19] With social desirability bias, we would expect teachers to say that the perform *all* activities more frequently

[20] We cannot tell what proportion of teachers did not respond, because children are randomly drawn at a school level, so we do not know how many teachers pupils with missing teacher data would have matched with.

[21] To reduce data capture error, we asked the fieldworker to only count pages completed for three specific days. We chose three days that should have been covered by teachers by the end of the year, regardless of their choice of sequencing.

3.2.3 Lesson observations

To gain a better understanding of how teaching practice changed in the classroom, we also conducted detailed lesson observations in October 2016 in a stratified random subset of 60 schools— 20 schools per treatment arm. We observed the lesson of one teacher per school. We stratified by school-average pupil reading proficiency in order to assure representation across the distribution of school performance. We also over-sampled urban schools, where the impacts of the programs were largest at midline.[22] An expert on early-grade reading developed the classroom observation instrument, in close consultation with Class Act and the evaluation team.

The instrument covered teaching and classroom activities that we expect to be influenced by the program. For example, the fieldworkers were required to record the number of pupils who read or handle books; the number of pupils who practice the different types of reading activities (this includes activities such as vocabulary development, phonics, word/letter recognition, reading sentences or extended texts); how reading is practiced in the classroom (e.g. read individually or in a group; read silently or aloud); and the frequency and types of writing activities taking place. The instrument also captured student-teacher interactions related to group-guided reading: whether reading groups are grouped by ability, how frequently pupils receive individual feedback from the teacher, and how frequently pupils are individually assessed. This final set of indicators mirror the questions that were asked in the teacher survey. The instrument was very detailed, but unlike some lesson observation instruments, did not require the fieldworkers to record time devoted to different activities. Rather, questions related to frequency of different activities were generally coded on a Likert scale.[23]

Since it was a detailed and comprehensive instrument, we decided to limit ourselves to six qualified fieldworkers, all of whom were proficient in Setswana and had at least a bachelors degree in education. To further assure consistency across fieldworkers, the project manager visited at least one school with each of the fieldworkers at the start of the data collection, and data quality checks were conducted on all data collected in the first two days.

After the completion of the lesson observations, the fieldworkers also asked some questions about the type of teaching support they received the past year. These were open-ended questions, which allowed us to code whenever a teacher mentioned receiving training or coaching from Class Act, or is using the program's graded reading booklets or lesson plans.

3.2.4 Administrative data

To add precision to our estimates, we further complemented these survey measures with 2011 census data and results from a standardized primary school exam conducted in 2014. From the 2011 census,

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[22] In particular, we randomly drew schools from each treatment group in the following manner: (i) six urban schools; (ii) five schools in the top tercile and five schools in the bottom tercile in terms of average performance across both baseline and midline; (iii) four schools in the top tercile in terms largest improvement between baseline and midline.

[23] For example, when coding frequency of different types of reading activities, the fieldworkers recorded: never, sometimes, mostly, and always.

we constructed a community wealth index derived from several questions about household possessions, and we also calculated the proportion of 13 to 18 year-olds in the community that are attending an educational institution.[24] We also have have data on each school's quintile in terms of socio-economic status, as coded by government.

3.2.5 Aggregation of indicators

In order to minimize the risk of over-rejection of the null hypotheses due to multiple different indicators, we aggregated data in the following ways. First, for own main outcome measure of success —reading proficiency— we combined all the sub-tasks into one aggregate score using principal components. We did this separately for each round of assessment. For the midline and endline scores, we used the factor loading of the control group to construct the index. This score was then standardized into a z-score: subtracting the control group mean and dividing by the standard deviation in the control. The treatment impact on the aggregate score can thus be interpreted in terms of standard deviations.

Furthermore, we grouped the potential mediating factors of changed teaching practice and classroom environment into five broad categories that are theoretically distinct inputs into learning to read: (i) curriculum coverage; (ii) fidelity to routine specified in curriculum; (iii) teacher-pupil interactions related to group-guided reading; (iv) frequency of practicing different reading activities; and (v) pupils' use of reading materials. For each category we created a mean index, using the method proposed by Kling et al. (2007), which is a average of the z-scores of all the constituent indicators.

3.3 Balance and descriptive statistics

Table 1 shows balance and basic descriptive statistics of our evaluation sample. Each row represents a separate regression of the baseline variable on treatment assignments and strata dummies, clustering standard errors at the school level. The first column indicates the mean in the control. Columns (2) and (4) indicate the coefficient on the treatment dummies. Column (6) reports the number of observations, and column (7) reports the p-value for the test of equality between Training and Coaching.

Our sample of schools come predominantly from poor communities: 46.3 per cent of schools are in bottom quintile in terms of socio-economic status, and 85 per cent are from rural areas. In only 44 per cent of schools do the majority of parents have a high school degree or higher. In almost all schools the main language spoken in the community is Setswana. A small fraction of classrooms ended up being multi-grade classrooms (6.2 percent of grade two classes). We were thus not perfectly able to identify and exclude *ex ante* all schools that do multi-grade teaching. The teachers are mostly female and are educated: 85 and 95 per cent of the grade one and two teachers respectively have a degree or diploma. Nonetheless, reading comprehension levels are low: The average score for the simple comprehension test is 66 per cent. The median number of Grade 2 teachers per school is one (57 percent of schools);

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[24] We acknowledge Stellenbosch University, and Asmus Zoch in particular, for constructing the dataset linking census data to schools data.

and one school has four teachers. We observe slight imbalance on baseline pupil reading proficiency and the school community's socio-economic status for the Training treatment arm. We control for all these variables in the main regression specification.

Panels (a) to (e) in Figure B.3 show the distribution of student scores by treatment status for each sub-task administered at baseline. Panel (f) shows the aggregate score. There are clearly floor effects for many of the sub-tasks, although there is a better spread for the aggregate score. Floor effects for baseline measures will not bias results, but could reduce statistical power. Panels (a) and (b) in Figure B.4 show distribution of the aggregate reading score at midline and endline. Our endline measure is normally distributed and shows no existence of ceiling or floor effects.

3.3.1 Sub-sample where we conducted lesson observations.

Table A.2. compares the sample where we conducted the lesson observations with the full evaluation sample. In each column we regress another independent variable on a dummy variable indicating whether the pupil/school is in the sample where we conducted the lesson observation. In columns (1) to (4) the data is at the individual level; in column (5) the data is at the school level. In column (1) the dependent variable is midline reading proficiency, including the full set of controls used in the main analysis (equation 1, below). A significant coefficient could thus be interpreted as the 'value-added', over and above the average learning trajectory of a pupil. Columns (1) to (4) in table A.2. show that there is no statistically significant difference between schools where we conducted the lesson observations and the rest of our evaluation sample, both in terms of pupil reading proficiency evaluated at baseline, midline and endline, and a value-added measure between baseline and endline. As expected given our sampling strategy, a far higher proportion of schools where we conducted lesson observations are urban: 36.7 per cent, compared to 20 per cent in our overall sample. Figure B.5 in the appendix further shows that the distribution of baseline and endline pupil reading proficiency is very similar, when comparing the lesson observation sample with the rest of the evaluation sample. When conducting the Kolmogorov-Smirnof equality of distribution test for the baseline and endline measures of reading proficiency, we cannot reject the null that the distributions are the same.

In addition, Table A.3 shows that the reduced sample where we conduct our lesson observations is balanced between treatment groups.

3.4 Empirical Strategy

Our main estimating equation is:

$$y_{icsb1} = \beta_0 + \beta_1(\text{Training})_s + \beta_2(\text{Coaching})_s + X'_{isb0}\Gamma + \rho_b + \varepsilon_{icsb1}, \tag{1}$$

where y_{icsb1} is the endline (end of second year) aggregate score of reading proficiency for pupil i who is taught by a teacher in class c, school s and strata b; $(\text{Training})_s$ and $(\text{Coaching})_s$ are the relevant treatment dummies; ρ_b refers to strata fixed effects; X_{icsb0} is a vector of baseline controls; and ε_{icsb1} is the error term clustered at the school level.

In order to increase statistical power, we control separately for each domain of reading proficiency collected at baseline: vocabulary, letter recognition, working memory, phonological awareness, word recognition, words read, and sentence comprehension. To further increase statistical power and account for any incidental differences that may exist between treatment groups, we control for individual and community-level characteristics which are highly correlated with y_{isb1} or were imbalanced at baseline.[25] Where data is missing for some observations for the control variables, we imputed missing values and added a dummy indicating missingness as a control.[26]

When we examine dynamic impacts, we reshape the data in a wide format and estimate:

$$\begin{aligned} y_{icsbt} = {} & \beta_0 + \beta_1 P_t + \beta_2(\text{Training})_s + \beta_3(\text{Training} \times P)_{st} \\ & + \beta_4(\text{Coaching})_s + \beta_5(\text{Coaching} \times P)_{st} + X'_{isb0}\Gamma + \rho_b + \varepsilon_{icsbt}, \end{aligned} \tag{2}$$

where $t \in (1,2)$ indicates the round of data collection, and P is a dummy variable set to one for endline data. The estimated coefficients, $\hat{\beta}_2$ and $\hat{\beta}_4$, now show the respective treatment impact at midline, and $\hat{\beta}_3$ and $\hat{\beta}_5$ show the improvements over time.

When investigating treatment impacts on teacher behavior, we estimate:

$$M_{cs} = \alpha_1 + \beta_1(\text{Training})_s + \beta_2(\text{Coaching})_s + \rho_b + \varepsilon_{csb1}, \tag{3}$$

where M_{cs} is the mediating variable of interest for a teacher in class c and school s. Standard errors are clustered at the school level for teacher survey data.[27] With classroom observation data we also include fieldworker fixed effects and day fixed effects, to account for the fact that not all teaching activities observed were supposed to take place at a daily basis, [28] Results are robust to the exclusion of fieldworker and day fixed effects.

Finally, when testing heterogeneous treatment impacts, we estimate the following equation:

$$\begin{aligned} y_{icsb1} = {} & \beta_0 + \beta_1(\text{Training})_s + \beta_2(\text{Coaching})_s + \beta_3(\text{Training} \times \sigma)_{ms} \\ & + \beta_4(\text{Coaching} \times \sigma)_m + X'_{icsb0}\Gamma + \rho_b + \varepsilon_{icsb1}, \end{aligned} \tag{4}$$

where σ_m is the moderating variable of interest, which could either be at the individual or class level, $m \in (c, i)$. The moderating variable is now also included in the vector of baseline controls. When the

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[25] The additional controls include: pupil gender, pupils' parents' education, district dummy (schools were randomly spread across two districts), performance in the most recent standardized Annual National Assessments (ANA), a community-level wealth index, and average secondary school attendance rate in the community surrounding the school.

[26] For categorical variables, we assigned missing values to zero; for continuous variables we assigned missing observations to equal the sample mean.

[27] We only observed one teacher per school in the classroom observations, so there is no need to cluster our standard errors at the school level. But we surveyed all the grade 2 teachers in each school, often more than one teacher per school.

[28] According to the lesson plans, creative writing is supposed to take place on Fridays, which provides fewer opportunities to practice reading.

moderating variable of interest is at a teacher/class level, we further re-weigh the observations so that each teacher/class receives equal weight.[29]

4 Results

4.1 Quality of implementation

As a first step in our analysis, we examine the quality of implementation. Rows (1) to (4) in Table 2 show results from the teacher questionnaire administered to all teachers in the evaluation sample. Rows (4) to (6) in Table 2 show results from the in-depth teacher survey conducted in a sub-set of 60 schools.

We see that that the program was well-implemented: 97 and 94 per cent of teachers in the Training and Coaching arms respectively state that they have received in-service training on teaching Setswana as a home language during that year. The support was also generally well-received: 45 and 66 per cent in the Training and Coaching arms respectively state they received very good support in teaching Setswana, relative to 17 per cent in the Control.[30] Teacher satisfaction also increased in the Coaching arm: teachers that received Coaching are 28.4 percentage points more likely to strongly agree with the statement: "I feel supported and recognized for their work". Moreover, results from the sample of teachers interviewed during the lesson observations reveal that exposure to the program was high: 79% and 90% of the regular grade 2 teachers in the Training and Coaching arms respectively state to use the program's lesson plans; 95 and 90 percent respectively claim to have received some training or support from Class Act; 95 percent in both treatment arms use the program's graded reading booklets; and 84 percent of teachers in the Coaching arm reported that they were visited by the program's reading coach that year.[31] The fact that compliance is not always 100% could be due to treated teachers transferring to another school, or assigned to another grade in the same school.[32]

It is also worth noting that the control teachers also received a high level of support from government. For example, over 79 per cent of teachers in the control received in-service training on teaching Setswana as a home language the past year; and 96 per cent of teachers have at least some graded reading booklets in the classroom. The results of this program should therefore be interpreted as impacts relative to the *status quo* of government involvement.

4.2 Impacts on learning

Next we turn to the mean impacts of the programs on student reading proficiency at endline. Table 3 shows the regression results on different indicators of reading proficiency, estimated using equation (1).

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[29] We have the same number of pupils per school, but due to random sampling of pupils, we do not have the same number of pupils per teacher/class.

[30] Although interestingly teachers in the Coaching arm are more likely to state that they received too much support.

[31] Four of the sampled teachers in the classroom observations were not the regular grade 2 teachers.

[32] Although we believe the latter is unlikely, since teachers typically teacher the same class for the duration of the year.

As recommended by Athey & Imbens (2017), the p-values are constructed using randomization-based inference.

We see from column (1) that Training and Coaching improved aggregate learning by 0.12 and 0.24 standard deviations respectively ($p = 0.175$ and $p = 0.001$). Column (2) shows that, for both treatment arms, the impacts are larger when we exclude students in multi-grade classrooms": 0.18 and 0.29 standard deviations respectively ($p = 0.041$ and $p < 0.001$). The program was never expected to be effective in such settings. Moreover, column (3) shows that the impacts are larger still when we exclude repeaters. These are students who had shorter exposure to the program, because they were not taught by the treated teachers in the second year.

Columns (4) to (10) further unpacks the results, looking separately at each domain of reading proficiency that constitutes the aggregate score. It is encouraging to note that Coaching had a statistically significant impact on learning across all the domains of reading proficiency at endline. The impact of Training, in contrast, was more muted: we only see statistical significance for phonological awareness and non-word decoding. The starkest difference between Training and Coaching is in comprehension ($p = 0.086$). This is arguably the most important indicator, since the ultimate goal of literacy is reading with comprehension.

Since there was imbalance in baseline learning in the Training arm (students in the Training were under-performing relative to the control), as a robustness check we test if the impact of Training varies dramatically if we exclude the worst-performing students from the Training arm. Moving from column (1) to column (4) in Table A.4, we see that there is only a very small change in the magnitude of the impact of Training as we consecutively trim a larger proportion of the sample in the Training arm: the 5^{th}, 10^{th}, and 15^{th} percentiles respectively in terms of baseline student performance. For comparison, columns (5) to (8) show the balance tests with the restricted sample: the difference between the Training and control is converging to zero as we restrict a larger proportion of the sample, and is no longer statistically significant after trimming the 5^{th} percentile. It therefore does not seem that imbalance is driving the smaller impact of the Training arm.

4.3 Dynamic impacts

Table 4 reports results on dynamic impacts, estimated using equation 2. The estimated coefficients in the first and third rows indicate the treatment impacts at midline, whereas the coefficients in the second and fourth rows show the improvements from midline to endline. Table A.5 in the appendix reports the same results, but in terms of standard deviations.

We see that students in the Coaching and Training arms experienced different trends over the two years of the program. The impacts are very similar in magnitude at midline— 0.13 and 0.141 standard deviations in the Training and Coaching treatment arms respectively ($p = 0.107$ and $p = 0.081$). However, over the course of the second year, students in the Coaching arm continued with their faster pace of learning relative to the control ($p = 0.131$), whereas students in the Training arm stagnated or even slightly reversed back to the control ($p = 0.842$). The difference in second-year treatment impacts between Training and Coaching is statistically significant ($p = 0.096$).

Moreover, columns (2) to (7) show that the dynamic impacts also vary by domain of reading proficiency. At midline, the largest impact for Coaching was phonological awareness (0.22 standard deviations, $p = 0.003$), and there were no statistically significant impacts on the number of letters and words read, nor paragraph reading. In the second year, the impacts on phonological awareness and writing actually decreased, but the impacts on reading of words, non-words and paragraphs accelerated in the Coaching arm. This is possibly because the teaching activities in grade 2 focused more on reading text, rather than recognition of sounds and letters.

4.4 Interpreting the magnitude of effect sizes

In order to interpret the magnitude of the effect sizes, we benchmark the results of this study both with the effect sizes of other similar programs, and with the learning that took place in the control. A recent meta-analysis of 44 evaluations of coaching programs in the United States found a pooled effect size of 0.11 SD on academic achievement for large-scale effectiveness studies with 100 teachers or more (Kraft et al. 2018). Conn (2014) found that the average impact of pedagogical interventions in sub-Saharan Africa was 0.228 standard deviations. A systematic review by McEwan (2015) found a mean effect of teacher professional development programs of 0.12 standard deviations. And a systematic review by Snilstveit et al. (2016) found that structured pedagogical programs have an average impact of 0.23 standard deviations on learning. Taken together, our estimated effect size of 0.232 standard deviations for Coaching is in line, and perhaps slightly larger than similar interventions implemented in developing countries.

When we benchmark the treatment impacts with learning that took place in the control, we focus on the two domains of paragraph reading and comprehension. The coefficient on "Endline" in Table 4 shows the growth that took place in the control over the second year of the evaluation. We estimate that the second-year impact of Coaching is equivalent to 26 percent ($4.34/16.62$) of the improvements in paragraph reading in the control. Moreover, since comprehension was not asked at midline, we can place an upper bound on learning by assuming that everyone in the control would have scored zero for the test at baseline. With this approach we estimate from Table 3 that Coaching is equivalent to at least 24 percent ($0.3/1.234$) of the learning that took place over the two years in the control.

4.5 Cost-effectiveness analysis

Since we found that the more costly program is more effective, it is important to determine which intervention was relatively more cost-effective. For thus purpose we calculate the ratio of gains to costs for two different outcomes: aggregate reading proficiency and performance in the comprehension test.[33] For

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[33] We consider the latter indicator, because reading with comprehension is arguably the ultimate goal of literacy development. We divide the score by 4 so the outcome is the proportion of questions answered correctly.

cost estimates we use the program budget for the second year of implementation, since implementation was likely more streamlined compared to the first year. We also exclude fixed costs of material development (lesson plans, training material, reading booklets), since its contribution to average per student cost will be nominal if the program gets scaled up.[34] Based on these estimates, the per student cost of the Training and Coaching programs are 31 USD and 43 USD per year respectively.[35] Table A.6. in the Appendix provides a breakdown of costs by category. The big cost driver for Training is the cost of the venue and paying for teachers' transport, food and accommodation. This cost is almost as high as the overall annual salary cost for the three coaches. The training also had many facilitators, with a teacher to facilitator ratio of roughly $7:1$.[36]

Given these estimates we conclude that Coaching is more cost-effective: it improves reading proficiency by 0.57 standard deviations per 100 USD spent per student per year, compared to 0.39 increase in the case of Training. Coaching is substantially more cost-effectiveness at improving reading comprehension, with a 17 percentage point improvement in the comprehension test per 100 USD spent per student per year, compared to a 6 percentage points in the Training arm.

It is perhaps surprising that Coaching is not more expensive relative to Training. Clearly there could be ways to reduce the cost of Training (for example, having a series of smaller workshops in a cluster of nearby schools, or reducing the number of facilitators, or reducing the number of training sessions, or not inviting the head teachers), but we do not know if the impacts would remain the same. Moreover, given the large differences in effect sizes, the cost of Training would need to be dramatically reduced before Training becomes more cost-effective.

4.6 Changing teaching practice

In this section we investigate underlying mechanisms by measuring how the learning environment, teaching practice, and classroom activities changed as a result of the program. For this purpose we draw from three different data-sources: the teacher survey and document inspection administered for the full evaluation sample of teachers, and lesson observations conducted in a stratified random sub-set of 60 schools. As discussed in section 3, we group the potential mediating factors into five broad categories: (i) curriculum coverage; (ii) adherence to the teaching routine as prescribed in the curriculum; (iii) teacher-pupil interactions related to group-guided reading; (iv) frequency of practicing reading; and (v) pupils' use of

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[34] A further challenge in allocating costs is that one organization jointly implemented both interventions, so some costs (such as program management, administration, and quality assurance) were shared across the programs. We asked Class Act to provide their best estimate of how time was allocated across the different interventions, and we allocated costs accordingly.

[35] The cost of implementing the program in 50 schools are $114,210$ USD and $160,221$ USD in the Training and Coaching arms respectively. Given an average size of 74.6 of students per school at the start of the program, this surmounts to per-student costs of 31 USD and 43 USD respectively. If we exclude overhead costs for Coaching and only consider the key variable costs— materials, salary and transport— then the per-pupil cost is 29 USD

[36] Note that the salary costs in the Training arm does not include the time that the coaches dedicates to training. The overall training salary costs would therefore be higher if the programs were implemented separately.

reading material. The regression results, estimated using equation 3, are reported in Tables 6 to 8.[37]

(i) Curriculum coverage Columns (1) to (5) in table 5 shows treatment impacts on curriculum coverage, as captured during document inspection. Overall we see that there was a statistically significant increase in curriculum coverage of similar magnitude for both Training and Coaching arms.

(ii) Teaching routine Row (1) to (6) in Table 5 show results on teacher self-reported frequency of performing different types of teaching activities on a weekly basis: group-guided reading, spelling tests, phonics, shared reading, and creative writing.[38] The frequencies of doing these activities are clearly stipulated in the government curriculum, so in principle the teachers in the Control should be performing them at the same frequency. We find that Training and Coaching schools are more likely to perform each activity at the appropriate level of frequency, especially for teachers that received Coaching. Moreover, the difference between Coaching and Training is statistically significant ($p = 0.02$). Note that the treated teachers are not stating that they are more likely to perform *all* activities. They are more likely to perform activities that should take place on a daily basis, group-guided reading and phonics, but less likely to perform the activity that should only take place only once a week, correcting spelling. At the very least, they show that the treated teachers have better knowledge of the appropriate routine they should follow.

(iii) Group-guided reading Next we unpack the type of teaching activities related to group-guided reading, an activity that teachers in both Training and Coaching arm report to perform more frequently. There are three important (and practically measurable) components of group-guided reading: individual attention from teachers, individual assessment, and sorting reading groups by ability. We asked for each one of these indicators separately in the teacher questionnaire, and also measured these activities during the lesson observations.

Rows (1) to (5) in Table 6 show result from the teacher survey. There was an overall increase for both treatment arms in the activities that relate to group-guided reading, with a consistently larger impact for Coaching relative to Training. First, as a confirmation of the self-reported increase in conducting group-guided reading, we find that program teachers were more likely to provide a list of reading groups relative to the control (16.8 and 34.4 per cent in the Training and Coaching arms respectively ($p = 0.091$ and $p < 0.001$)), and this impact is significantly larger for teachers that received Coaching ($p = 0.0748$). We further find that teachers who received Coaching were more likely, compared to Training and Control teachers, to listen to students read out loud and perform one-on-one reading assessments.[39] Teachers in both Training and Coaching are more likely to state that they stream groups by ability.

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[37] Many of the indicators are ordinal variables, but for ease of interpretation we report results for adapted binary variables. Results on statistical significance remain the same when running an ordered logit model on the ordinal variables; and the mean index is constructed using the ordinal variable, thus preserving all the information captured by fieldworkers.

[38] Options were: Less than once a week, once a week, 2-4 times a week, every day, twice a day.

[39] Original variables are ordinal ranging from 1 “Never” to 5 “Nearly every day”.

The results from the teacher survey provide evidence that group-guided reading was far more likely to take place in both treatment arms, with the largest increase observed for teachers who received Coaching. However, these results are all self-reported. To test if these practices actually changed in the classroom, we next turn to results from the lesson observations.

Rows (6) to (11) in Table 6 show that the results from the teacher survey on group-guided reading are broadly supported by the lesson observations: there is a large increase in the mean index of 0.58 and 0.635 standard deviations in the Training and Coaching groups respectively ($p = 0.031$ and $p = 0.009$). When examining the different components of group-guided reading, we see that there is a large increase in the Coaching arm in the probability that students read aloud in groups (37.8 percentage point increase, $p = 0.022$), and that the students read individually to the teacher (39.7 percentage point increase, $p = 0.059$).[40] The impact for these two indicators is smaller for the Training arm, and not always statistically significant. However, we do not find strong evidence for any improvement in the probability of providing individual assessment and grouping by ability.[41]

Note that not *all* types of reading activities are more likely to take place. For sake of comparison, rows (12) to (14) show that teachers are no more likely to perform whole-class reading, where the whole class reads aloud with the teacher. Teachers are also no more/less likely to read aloud with the students following silently. Whole-class reading is an easy activity to perform in the classroom, and almost all teachers in the control are already doing it.

(iv) Practicing reading and phonics Results from rows (1) to (10) in table 7 show that students are no more likely to practice reading in the classroom because of the programs, nor is there any evidence that teachers are more likely to teach phonics.[42] Although the mean index for reading frequency is not significant, we see in columns (8) and (9) that students in both the Training and Coaching arms are more likely to read extended texts (3-5 sentences).

(v) Student use of reading material Rows (11) to (13) in Table 7 report results on use of books and reading material. We see a substantial increase in use of reading material, especially in the number of children who have opportunities to read. The average number of students who read the booklets increased by 1.6 and 4.6 in the Training and Coaching arms respectively ($p = 0.057$ and $p = 0.002$). The difference between Training and Coaching is large and statistically significant at the 1 percent level, this despite the fact that teachers in both treatment arms received the same number and type of reading booklets. Note

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[40] These indicators were first recorded as ordinal variables ranked from 1 to 4. For ease of interpretation we created a binary indicator for these two indicators, indicating if *any* activity took place.

[41] There is a small increase in the probability of providing individual assessment, which is statistically significant only in the Training arm.

[42] The fieldworkers were asked to record how many students in the classroom are involved with reading letters, words, sentences, or extended texts. The answers were recorded as 5-point Likert scale, ranging from none to all the students. They also recorded the extent to which teacher covers phonics on a 4-point Likert scale. As before we construct binary variables for ease of interpretation (equal to one, if at least some students are reading; and equal to one if the teacher teaches phonics at least some of the time).

that the graded reading booklets are meant to be used during group-guided reading.

To summarize, for both treatments we find improvements in curriculum coverage and teaching practice. Moreover, Coaching had a larger impact relative to Training in activities related to group-guided reading: more students received individual attention from a teacher and opportunities to practice reading aloud; and more students were reading the graded reading booklets. This result is consistent with the observation that students in the Coaching arm progressed at a faster pace in "higher-order" domains of reading proficiency, such as paragraph reading and reading comprehension, relative to students whose teachers receiving Training.[43] But can these improvements in teaching practice be uniquely attributed to the learning gains? We turn to this question below.

4.7 Mediation analysis

What proportion of the treatment-induced learning gains can be explained by improvements in teaching practice? To answer this question, we conduct mediation analysis, employing both the linear structural equation model (see, for example Imai et al. (2010)) and the sequential *g* estimation as proposed by Acharya et al. (2016). Both approaches make strong identifying assumptions, so these results should be merely treated as suggestive. Section A in the appendix describes the methods in more detail.

Panel A in Table 8 report regression outputs for the linear structural equation model. Column (1) shows the regression results from equation 1, restricted to pupils for whom we also have teacher data. The regressions in rows (2) to (18) successively include a different mediating variable as one of the independent variables. We consider all the intermediate outcomes collected from the teacher survey and document inspection. We do not report any results for data collected during lesson observations, because limited sample size means that we do not have sufficient statistical power to draw any definitive conclusions.[44] The row headings indicate the mediator of interest.

Two trends are worth highlighting. First, we see from column (1) in rows (14) to (18) that there is a statistically significant positive relationship between learning and almost all variables related to group-guided reading, even after controlling for treatment assignment. For example, row (15) shows that pupils taught by a teacher who could produce a list of reading groups scored on average 0.159 standard deviations higher, compared to pupils taught by teachers who could not produce a reading list. These results suggest that at least part of the treatment impacts are driven by an increase in the probability that teachers enact group-guided reading in the classroom. In contrast, there is no positive relationship between curriculum coverage and learning. The positive relationship between routine and learning is driven, in part, by increased propensity to conduct group-guided reading. Second, by comparing the regression results

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[43] In contrast, the programs had a similar impact on phonological awareness. Phonics is typically taught using "whole class" teaching activities, which is easy to do and already widely implemented.

[44] After matching lesson observation with students learning data, we are left with a sample of 53 teachers, compared to 275 teachers from the survey data.

in row (1) with the subsequent regressions, we see that the treatment impact of Coaching is reduced by 25 percent (from 0.281 to 0.212), after accounting for the contribution of group-guided reading to learning.

Panel B, row (19), reports regression outputs for the final step of the sequential g estimation. This approach is considered an improvement to Imai et al. (2010), since it allows one to control for additional post-treatment confounders.[45] For possible confounders, we include the mean indices for curriculum coverage and routine, and also an index of the print richness in the classroom. The coefficient estimates can be interpreted as what the treatment impacts would have been, if it had no impact on group-guided reading. The reduction in treatment impacts from row (1) to row (19) thus captures the indirect effect: the share of the treatment impact which is explained by treatment-induced changes in the mediator. With this approach as much as 68 percent of the treatment impact of Coaching is mediated by changes in group-guided reading.

We therefore have suggestive evidence that improvements in group-guided reading is at least partly responsible for the gains in reading proficiency of the Coaching arm.

4.8 Heterogeneous treatment impacts

How do the impacts of the interventions depend on the characteristics of the student, teacher and the class? Table 9 displays the regression results on heterogeneous treatment impacts, estimated using equation 4.[46] Columns (1) to (4) show that effect sizes do not depend on observable teacher characteristics, such as teacher qualifications, age, experience, and the number of books that the teacher has read in a year. Columns (5) and (6) how that, although there is no linear relationship between the number of students in a classroom and effect size, there is a strong non-linear (positive concave) relationship.

To further unpack this non-linear relationship, Panels A and B in Figure 2 show local polynomial regression estimates of the relationship between effect size and class size percentile rank. We observe that for both interventions the effect sizes are largest for intermediate-sized classes, peaking at roughly the 35^{th} percentile (38 students per class). The treatment impacts are statistically indistinguishable from zero in the very large and very small classes.[47] For comparison, Panel C shows the non-parametric relationship between improvements in student learning and class size in the control schools. We see that control students in very small classes (up to roughly the 15^{th} percentile) learn at a faster pace than the rest of control students. Taken together, it seems that both treated and control teachers perform *equally well* in the smallest classes, but perform *equally badly* in the largest classes.

One possible interpretation for this non-linear relationship is that the new teaching techniques and learning materials allow teachers to overcome some constraints to student learning that are present in

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[45] Although it still makes the strong assumption that we have controlled for *all* post-treatment confounders that are correlated with both the mediator and the outcome.

[46] In all future analysis we drop the small sample of multi-grade classes. We do not want any trends we observe to be driven by these schools. Results are robust to including these schools.

[47] Panel A in Figure B.6 shows the treatment impact by quartile of class size. For both treatments, the difference in effect sizes between the middle two quartiles and the extreme quartiles of class size is statistically significant ($p < 0.001$). As a reference point, the 25^{th} and 75^{th} percentiles have class sizes of 35 and 46 students per class.

larger classes, but teachers are either unable to implement these techniques in the largest classes, or these techniques are less effective in the largest classes. For example, since control teachers mostly perform "whole class" teaching (the whole class reads aloud with the teacher), it is plausible that students in larger classes are less likely to receive individual feedback from a teacher and have fewer opportunities to practice reading, compared to smaller classes. In contrast, group-guided reading activities can provide students with these opportunities. However, teachers might find it impossible to implement group-guided reading in extremely large classes;[48] or, group-guided reading becomes less effective on average since a lower proportion of students get opportunities to read in front of the teacher on any given day.

Turning to student-level interactions, Panels A and B in Figure 3 show local polynomial regression estimates of the relationship between effect size and a student's percentile rank in terms of baseline academic performance. We see that in the Coaching arm students who performed worse at baseline benefit least from the program. In fact, Panel B in Figure B.6 in the appendix shows that there is no statistically significant impact for the bottom fifth of students. Panels A and B in Figure 4 shows that the impact does not vary by a student's relative rank within her class. This suggests that the pupil's absolute level of reading proficiency is the constraint to learning, rather than her relative position in the class.

There can be many possible explanations for this trend, none of which we can conclusively rule out. It could be because the worst-performing students do not have a strong enough foundation to benefit from the new teaching techniques. The teachers might be covering curriculum at too fast a pace, or applying curriculum that is too ambitious to start off with. Or it might be that these students lack other complementary inputs to reading acquisition, such as literate and involved parents; or because weaker students are more likely to be in worse-quality schools that are less responsive to the treatments.

5 Conclusion

We report the results of a randomized evaluation of two different approaches to improving the instructional practices of early-grade reading teachers in public primary schools in South Africa. The first approach (Training) follows the traditional model of a once-off training conducted at a central venue. In the other approach (Coaching), teachers are visited on a monthly basis by a specialist reading coach who monitors teaching, provides feedback, and demonstrates correct teaching practices. We find that Coaching had a large and statistically significant impact on student reading proficiency, more than twice the size of the Training arm. Coaching was also more cost-effective.

Detailed classroom observations and document inspection gives insight into which teaching practices changed. We find that teachers in both treatments are more likely to practice a difficult teaching technique called group-guided reading: students are more likely to read aloud in smaller groups, and receive individual attention from their teacher when they are reading. In contrast, teachers in the control most typically conduct "whole-class" teaching, where the whole class reads aloud with the teacher. Students

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[48] Teachers complained during the exit surveys that group-guided reading is too difficult to implement in large classes.

are also more likely to handle books and read the graded reading booklets— an activity that is supposed to take place during group-guided reading. This impact is larger for teachers that received Coaching, compared to Training. Furthermore, mediation analysis shows that improvements in group-guided reading explain a large proportion of learning gains in the Coaching arm.

These results suggest that coaches play an important role in the adoption of more technically challenging teaching techniques. Group-guided reading is particularly difficult to implement: teachers need to re-organize the classroom and keep the rest of the classroom busy as they provide targeted feedback to the smaller reading group. Indeed, during the exit surveys, teachers complained that group-guided reading is difficult, especially in larger classes, and that the training was too short for them to fully understand group-guided reading.

Our finding on the use of reading material also reveal important complementarities in the education production function between access to resources, teaching practice, and use of resources. The purpose of the graded readers is to provide opportunities to practice reading. Pupils are provided this opportunity during group-guided reading, an activity that teachers find challenging to implement. These resources therefore cannot be used without appropriate enactment of a new teaching method. Coaching thus enabled teachers to use more effectively the resources that are available to them.

It is important to note that both programs are bundled interventions, so we cannot attribute the learning gains exclusively to the coaching/training component. For example, the lesson plans might have had the same impact in the Training arm even in absence of training, and the Training/Coaching arms might have had no impact if not combined with learning aids and lesson plans. This is an inevitable limitation to evaluating bundled interventions. But this is also a strength of the program, since it was designed with the premise that the different components complement each other.

How generalizable are these results to other contexts? Seen in the context of other evaluations of similar programs, we feel it is likely that these results are generalizable, at least for improving early-grade reading within sub-Saharan Africa. Other studies in sub-Saharan Africa have found that the combination of reading coaches and supporting learning material can improve students' proficiency in early-grade reading (Piper et al. 2014, 2018, Lucas et al. 2014, Kerwin et al. 2017). Moreover, a previous quasi-experimental evaluation of a very similar coaching program in a different province in South Africa also found positive impacts on learning (Fleisch et al. 2016), even though the context was very different: schools in this study are predominantly urban and multilingual. However, we clearly cannot conclude that this type of intervention will have similar impacts when targeted at different grade levels or subjects areas.

Looking forward, a key question is if and how the Coaching program can be scaled up. Capacity and resource constraints makes us hesitant to conclude that government should scale the program as currently designed. The per-pupil cost of Coaching is a small fraction of government's overall education budget (roughly 8.6 percent), but is a large fraction of government's discretionary budget.[49] Government could

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[49] 80-90 percent of the budget is earmarked to teacher salaries

rely on existing staff, such as the district-appointed subject advisors, to do the coaching. But is unclear if they will have the right capacity and set of incentives to provide the appropriate support. This program relied on only three coaches, and it was implemented by a non-governmental organization with strong incentives to demonstrate positive impact. We do not know if coaches will have the same impact if they are less-qualified, or visit less often, or connect remotely rather than in person.

Nonetheless, the quasi-experimental evidence from Fleisch et al. (2016) provides encouraging evidence that this could be a scalable model, since the program was implemented in over $1,000$ schools. Moreover, the fact that teacher behavior changed in the Training arm, without any visits by a reading coach, suggests the possibility of positive impact, even with less-qualified coaches. And scaling does not mean it needs to be implemented in all schools at the same time: it could be staggered implementation, where the same group of reading coaches visit a different cluster of schools every couple of years.

In sum, we believe the program has potential to be implemented at a larger scale, but there are many unanswered questions: Does the coaching model rely on highly-qualified coaches, or could the mere act of monitoring teaching encourage practice and thus facilitate the adoption of new teaching techniques? Can virtual coaching have the same impact as in-person coaching? Can a year of coaching lead to a sustained change in teaching practice? These questions will be a focus of future research.

6 Tables and Figures

Table 1. Descriptive and balance statistics

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Control	*Training*		*Coaching*			*Training = Coaching*
	Mean	Coef.	Std error	Coef.	Std error	Obs	P-value
Pupil Characteristics							
Age	6.481	0.078	(0.0520)	-0.0244	(0.0524)	3,523	0.0669
Female	0.479	-0.016	(0.0220)	-0.0120	(0.0207)	3,518	0.884
Reading proficiency	0.0380	-0.209*	(0.118)	0.0666	(0.146)	3,539	0.0658
Grd 2 Teacher Characteristics							
Diploma or degree	0.947	0.013	(0.0312)	0.0413	(0.0253)	271	0.262
Age	48.92	-1.566	(1.365)	-0.287	(1.217)	273	0.311
Female	1	-0.0138	(0.0134)	0.00001	(0.00234)	271	0.305
Experience	19.43	-1.147	(1.614)	-0.318	(1.498)	271	0.597
Books read	3.109	-0.0307	(0.553)	0.551	(0.793)	260	0.482
Class size	42.17	-1.993	(1.464)	-3.174**	(1.589)	271	0.420
Multi-grade	0.0619	0.00698	(0.0333)	0.00253	(0.0293)	271	0.905
Comprehension test	0.663	-0.0425	(0.0304)	-0.00419	(0.0326)	269	0.237
School characteristics							
Setswana most common	1	-0.0418	(0.0284)	-0.0216	(0.0213)	167	0.559
Most parents - highschoo	0.443	-0.106	(0.0871)	0.0341	(0.0823)	179	0.129
Rural	0.850	-0.0700	(0.0679)	-0.110	(0.0691)	180	0.623
Bottom quintile (SES)	0.463	0.0975*	(0.0520)	-0.0425	(0.0392)	180	0.007
Pass rate (ANA)	55.35	-1.184	(0.894)	-0.981	(0.917)	180	0.845
Wealth index	-3.077	-0.522	(0.497)	-0.616	(0.496)	180	0.853
Kenneth district	0.212	-0.0125	(0.0705)	0.0875	(0.0771)	180	0.223

Notes: Each row indicates a separate regression on treatment dummies controlling for strata indicators. Column one shows the control mean, columns (2) and (4) the coefficient on the two treatment dummies. Standard errors are indicated in columns (3) and (5) and are clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1

Table 2: Implementation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	General support in teaching Setswana				*Exposure to Class Act (in-depth teach survey)*			
	Received training	Feel supported & respected	Very good support	>0 graded readers	Received training/support	Graded readers	Lesson plans	Reading coach
Training	0.179***	0.0874	0.287***	0.0300	0.952***	0.761***	0.783***	0.0884
	(0.0471)	(0.0744)	(0.0696)	(0.0272)	(0.0483)	(0.121)	(0.123)	(0.0932)
Coaching	0.148***	0.284***	0.490***	0.0342	0.994***	0.752***	0.957***	0.892***
	(0.0514)	(0.0692)	(0.0637)	(0.0266)	(0.0249)	(0.117)	(0.0832)	(0.0938)
Observations	274	274	272	263	56	56	56	56
R-squared	0.106	0.104	0.232	0.054	0.942	0.792	0.704	0.755
Training mean	0.974	0.618	0.447	0.986	0.947	0.947	0.789	0.0526
Coaching mean	0.939	0.817	0.659	0.987	0.950	0.900	0.900	0.842
Control mean	0.793	0.534	0.167	0.956	0	0.111	0.0556	0

Notes: each column represents a separate regression, including strata fixed effects. Data from columns (1) to (4) come from the teacher questionnaire administered to all teachers in the evaluation sample. The dependent variable in column (4) is a dummy variable indicating if a teacher has access to least one graded reader. Data from columns (5) to (8) come from the in-depth teacher survey conducted in a sub-set of 60 schools. Observations are at a teacher level. Standard errors are clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1

Table 3. Main results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	Aggregate reading score			Phon. awareness	Letters	Words	Non-words	Paragraph reading	Comprehension	Writing
Training	0.116	0.177**	0.234***	0.150**	1.572	1.754	1.76	3.016	0.0695	0.248
	(0.0791)	(0.0814)	(0.0884)	(0.0706)	(2.345)	(1.333)	(1.042)	(1.833)	(0.0980)	(0.186)
Coaching	0.242***	0.290***	0.363***	0.168**	5.056**	3.804***	3.557***	5.711***	0.300***	0.368*
	(0.0778)	(0.0802)	(0.0883)	(0.0765)	(2.445)	(1.241)	(1.025)	(1.686)	(0.0965)	(0.201)
Excluding multi-grade	No	Yes	Yes	No	No	No	No	No	No	No
Excluding repeaters?	No	No	Yes	No	No	No	No	No	No	No
Observations	2,951	2,764	2,329	2,951	2,951	2,951	2,951	2,951	2,951	2,951
R-squared	0.169	0.172	0.169	0.071	0.147	0.158	0.142	0.151	0.121	0.124
Training=Coaching:P-value	0.181	0.190	0.153	0.855	0.222	0.189	0.16	0.215	0.051	0.616
Mean in control										
Baseline	0	0	0	0.942	5.406	1.994	0	0	0	0
Endline	0	0	0	1.738	39.04	18.91	13.69	24.48	1.234	5.898

Notes: Each column represents a separate regression, using equation (1). All specificaitons include the following controls: baseline reading proficiency, gender, parents' education, school performance in standardized national exam, a district dummy, a community-level wealth index and highschool attendance rates. In column (2) the sample is restricted to schools that do not have multi-grade classrooms. In column (3) both multi-grade classes and grade repeaters are excluded from the sample. Standard errors are in parentheses and clustered at the school level. P-values are constructed using randomization inference. *** p<0.01, ** p<0.05, * p<0.1

Table 4. Dynamic impacts

	VARIABLES	(1) Aggregate score	(2) Phon. awareness	(3) Letters	(4) Words	(5) Non-words	(6) Paragraph	(7) Writing
(1)	Training	0.129	0.116	1.826	1.035	1.328**	2.018*	0.694**
		(0.0798)	(0.0902)	(1.932)	(0.789)	(0.638)	(1.130)	(0.271)
(2)	Training x endline	-0.0124	0.0602	-0.809	0.305	0.0370	0.465	-0.410*
		(0.0619)	(0.101)	(1.828)	(1.056)	(0.834)	(1.425)	(0.239)
(3)	Coaching	0.141*	0.280***	3.169	0.747	1.037*	1.400	0.532*
		(0.0804)	(0.0913)	(2.059)	(0.772)	(0.624)	(1.091)	(0.307)
(4)	Coaching x endline	0.100	-0.118	1.524	2.948***	2.451***	4.344***	-0.120
		(0.0661)	(0.107)	(2.360)	(1.021)	(0.867)	(1.363)	(0.270)
(5)	Endline	-0.00645	1.079***	16.19***	11.85***	9.414***	16.62***	0.136
		(0.0429)	(0.0692)	(1.563)	(0.731)	(0.547)	(0.937)	(0.147)
	Mean in control							
(6)	Baseline	0	0.942	5.406	1.994	0	0	0
(7)	Midline	0	0.654	22.70	6.978	4.220	7.763	5.737
(8)	Endline	0	1.738	39.04	18.91	13.69	24.48	5.898
(9)	Training x Endline=Coaching x Endline: P-value	0.0956	0.108	0.246	0.0123	0.00974	0.00883	0.322
(10)	Observations	6,190	6,190	6,190	6,190	6,190	6,191	6,190
(11)	R-squared	0.171	0.251	0.232	0.296	0.275	0.284	0.124

Notes: Each column represents a separate regression, using equation (2). The controls are the same as in Table 3. Standard errors are in parentheses and clustered at the school level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5. Curriculum coverage and routine

		(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Control	*Training*		*Coaching*			Training = Coaches
		mean	Coef.	Std. Error	Coef.	Std. Error	Obs	p value
Currciculum coverage								
(1)	*Kling index*	0	0.469***	(0.128)	0.317**	(0.139)	271	0.343
	Days pupil completed:							
(2)	---Any exercises	23.57	16.64***	(3.348)	5.007	(3.778)	270	0.00679
(3)	---Writing exercises	19.08	8.532***	(3.046)	6.306*	(3.478)	270	0.581
(4)	---Full sentence writing exercises	14.11	9.736***	(3.155)	5.539*	(3.044)	270	0.264
(5)	Proportion of pages completed	0.761	-0.0441	(0.0555)	0.0840**	(0.0423)	258	0.0185
Routine								
(6)	*Kling index*	0	0.300***	(0.0811)	0.497***	(0.0652)	276	0.0209
(7)	Group-guided reading	0.241	0.124*	(0.0738)	0.197***	(0.0674)	274	0.363
(8)	Spelling test	0.696	0.155**	(0.0627)	0.238***	(0.0509)	273	0.143
(9)	Phonics	0.491	-0.0708	(0.0745)	0.171**	(0.0720)	274	0.00195
(10)	Shared reading	0.422	0.183**	(0.0728)	0.171**	(0.0711)	274	0.872
(11)	Creative writing	0.310	0.301***	(0.0715)	0.383***	(0.0681)	274	0.286

Notes. Each row represents a separate regression, including strata fixed effects. Data is at the teacher level. Standard errors are clustered at the school level
*** p<0.01, ** p<0.05, * p<0.1

Table 6. Types of reading activity

		(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Control	*Training*		*Coaching*			Training = Coaching
			Coef.	Std. error	Coef.	Std. error	Obs	P-value
Group-guided reading (questionnaire)								
(1)	*Kling index*	0	0.210**	(0.0880)	0.415***	(0.0772)	276	0.0124
(2)	Teacher can provide list of groups	0.430	0.168*	(0.0987)	0.344***	(0.0815)	232	0.0748
(3)	Listen to each pupil read out loud (almost daily)	0.578	0.0324	(0.0772)	0.237***	(0.0638)	273	0.00714
(4)	One-on-one reading assessment (at least weekly)	0.655	0.0877	(0.0755)	0.161**	(0.0638)	274	0.296
(5)	Stream by ability	0.718	0.107*	(0.0579)	0.144**	(0.0580)	261	0.527
Group-guided reading (lesson observations)								
(6)	*Kling index*	0	0.580**	(0.260)	0.635***	(0.230)	60	0.844
(7)	Pupils read aloud in groups	0.444	0.0604	(0.174)	0.378**	(0.157)	54	0.0613
(8)	Pupils read individually to teacher	0.176	0.297*	(0.175)	0.397*	(0.202)	51	0.614
(9)	Individual reading assessment	0.158	0.129	(0.143)	0.00326	(0.135)	55	0.417
(10)	Reading groups, different texts	0.105	0.0421	(0.155)	0.0906	(0.123)	52	0.807
Whole class reading								
(11)	Teacher reads, class not following	0.222	-0.263	(0.161)	-0.0455	(0.135)	50	0.169
(12)	Teacher reads, class following silently.	0.550	-0.0312	(0.162)	0.0201	(0.194)	52	0.753
(13)	Whole class reads aloud with teacher	0.833	-0.0119	(0.169)	0.149	(0.114)	50	0.279

Notes. Each row represents a separate regression, including stratification fixed effects. Data is at the teacher level. Data from rows (1) to (5) come from the teacher survey conducted in the full evaluation sample. Data from rows (6) to (14) come from lesson observations conducted in a sub-sample of 60 schools. Regressions from rows (6) to (14) also include day-of-the-week and fieldworker fixed effects. *** p<0.01, ** p<0.05, * p<0.1

Table 7 . Frequency of reading activity and use of reading material

		(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Control	*Training*		*Coaching*			Training = Coaching
		mean	Coef.	Std. error	Coef.	Std. error	Obs	P-value
Reading frequency								
(1)	*Kling index*	0	0.0598	(0.121)	0.139	(0.110)	60	0.582
(2)	Phonics	0.684	0.230	(0.159)	0.207	(0.189)	59	0.886
(3)	Letters	0.625	-0.157	(0.189)	0.0374	(0.168)	49	0.260
(4)	1-2 words	0.471	-0.0321	(0.154)	0.166	(0.138)	44	0.226
(5)	3-10 words	0.667	-0.153	(0.136)	0.0990	(0.140)	52	0.0150
(6)	10+ words	0.133	0.126	(0.164)	0.284*	(0.144)	40	0.218
(7)	1-2 sentences	0.529	-0.255	(0.212)	-0.0373	(0.242)	44	0.298
(8)	3-5 sentences	0.333	0.349**	(0.163)	0.432***	(0.138)	48	0.604
(9)	5+ sentences	0.188	0.177	(0.209)	0.238	(0.163)	49	0.758
(10)	Extended texts	0.579	0.0895	(0.191)	0.188	(0.211)	55	0.558
Use of reading material								
(11)	*Kling index*	0	2.662	(1.940)	10.73***	(3.077)	60	0.00325
(12)	No. learners read readers	0.0526	1.664*	(0.847)	4.593***	(1.346)	57	0.00529
(13)	No. learners handle books	1	0.0346	(0.847)	2.176*	(1.159)	59	0.0343

Notes. Each row represents a separate regression, including stratification, day-of-the-week and fieldworker fixed effects Data is at the teacher level, each teacher at a different school. Standard errors are clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1

Table 8. Mediation Analysis

	MEDIATORS	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Mediator		Training		Coaching		Obs
		Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	
Panel A. Linear Structureal Equation Model (Imai et al, 2010)								
(1)	No mediator			0.168**	(0.0840)	0.281***	(0.0833)	2,393
Currciculum coverage								
(2)	*Kling index*	-0.0803*	(0.0419)	0.207**	(0.0915)	0.311***	(0.0894)	2,355
(3)	Days pupil completed:							
(4)	---Any exercises	-0.00381**	(0.00156)	0.234**	(0.0956)	0.311***	(0.0877)	2,341
(5)	---Writing exercises	-0.00312*	(0.00167)	0.194**	(0.0888)	0.305***	(0.0887)	2,342
(6)	---Full sentence writing exercises	-0.00125	(0.00172)	0.180*	(0.0933)	0.289***	(0.0918)	2,342
(7)	Proportion of pages completed	-0.0146	(0.143)	0.189**	(0.0917)	0.304***	(0.0927)	2,242
Routine								
(8)	*Kling index*	0.300*	(0.166)	0.103	(0.0913)	0.217**	(0.0984)	2,377
(9)	Group-guided reading	0.128*	(0.0699)	0.133	(0.0891)	0.262***	(0.0902)	2,377
(10)	Spelling test	0.0550	(0.0866)	0.140	(0.0927)	0.272***	(0.0933)	2,373
(11)	Phonics	-0.0212	(0.0662)	0.147	(0.0899)	0.287***	(0.0886)	2,377
(12)	Shared reading	0.0595	(0.0639)	0.137	(0.0896)	0.273***	(0.0872)	2,377
(13)	Creative writing	0.133*	(0.0722)	0.107	(0.0912)	0.234**	(0.0934)	2,377
Group-guided reading								
(14)	*Kling index*	0.193***	(0.0557)	0.0975	(0.0910)	0.212**	(0.0891)	2,393
(15)	Teacher has list of groups	0.141*	(0.0806)	0.148	(0.0990)	0.219**	(0.0950)	1,983
(16)	Listen to each pupil read out loud (almost daily)	0.193***	(0.0634)	0.142	(0.0899)	0.240***	(0.0874)	2,369
(17)	One-on-one reading assessment (at least weekly)	0.207**	(0.0840)	0.123	(0.0902)	0.250***	(0.0885)	2,377
(18)	Stream by ability	0.112	(0.0777)	0.130	(0.0920)	0.278***	(0.0867)	2,266
Panel B. Sequential g-estimation (Acharya et al, 2016)								
(19)	Group-guided reading (Kling index)			0.187**	(0.0838)	0.0909	(0.0818)	2,295

Notes. Each row represents a separate regression. In rows (1) to (18) aggregate reading proficiency is the dependent variable. Data is restricted to grade 2 pupils for whom we have teacher data. Row (1) is estimated using equation (1), including the same set of controls as Table 3. Rows (2) to (18) include the same set of controls as row (1), as well as a mediating post-treatment variable. The row headings indicate the mediating variable that is included in the regression. The dependent variable in row (19) is the demediated outcome, calculated using equations (6) and (7) in the Appendix, where the mediator is the index for group-guided reading, and potential post-treatment confounders are the indices for curriculum coverage, routine, and print-richness in the classroom. Standard errors are clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1

Table 9. Teacher, class, and pupil-level interaction effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Group	Degree	Books read	Age	Experience	Class size		Baseline pupil score
(1) Training	0.171	0.202*	0.501	0.275	0.0820	-2.747***	0.231***
	(0.139)	(0.113)	(0.451)	(0.167)	(0.411)	(0.976)	(0.0839)
(2) Training x group	0.0299	0.00512	-0.00611	-0.00382	0.00230	0.141***	0.0387
	(0.179)	(0.0187)	(0.00909)	(0.00761)	(0.00971)	(0.0492)	(0.0934)
(3) Training x group squared						-0.00164***	-0.0928**
						(0.000604)	(0.0358)
(4) Coaching	0.306**	0.413***	1.007**	0.558***	-0.181	-2.916***	0.310***
	(0.144)	(0.111)	(0.469)	(0.159)	(0.412)	(0.824)	(0.0810)
(5) Coaching x group	0.123	-0.0220	-0.0137	-0.0111	0.0123	0.153***	0.182*
	(0.173)	(0.0147)	(0.00966)	(0.00719)	(0.0101)	(0.0408)	(0.104)
(6) Coaching x group squared						-0.00172***	-0.0517*
						(0.000499)	(0.0276)
Excl. repeaters?	Yes	Yes	Yes	Yes	Yes	Yes	No
Observations	1,932	2,030	2,137	2,112	2,121	2,121	2,764
R-squared	0.175	0.163	0.173	0.171	0.178	0.189	0.190

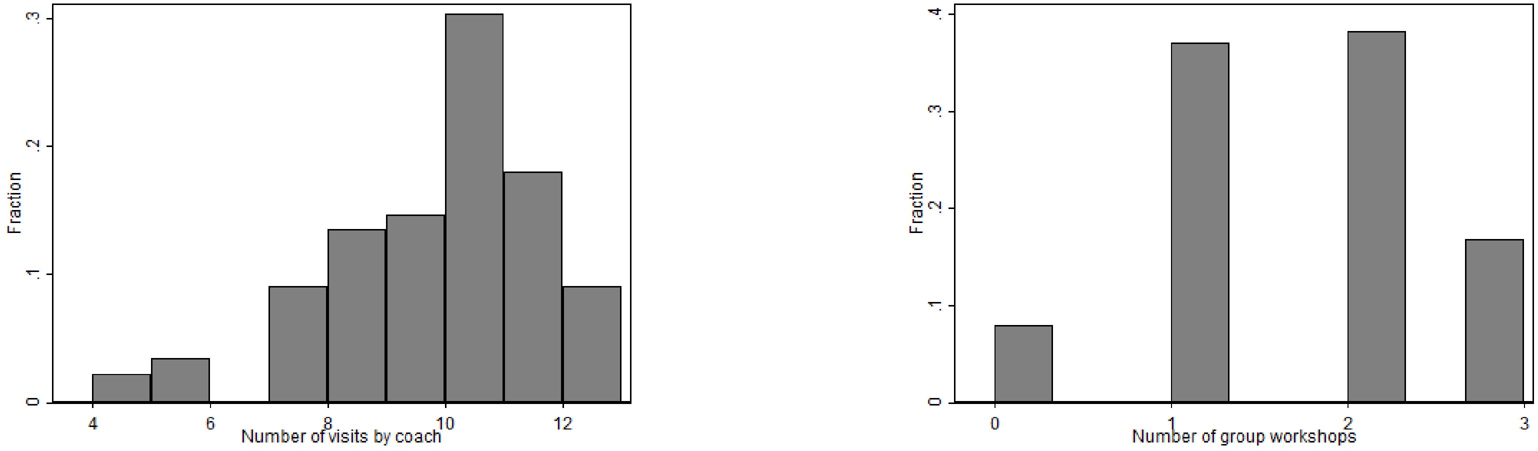
Notes: Each column represents a separate regression, estimated using equation (3) and including the same set of controls as in Table 3. Column headings indicate the variable that is being interacted with treatment dummies. Standard errors are in parentheses and clustered at the school level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 10. Group-guided reading by class size

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Kling index	Teacher has list of groups	Listen to each pupil read out loud	One-on-one reading assessment	Stream by ability	Group-guided reading
Training	1.216***	1.216**	0.686**	0.272	0.224	-0.209
	(0.397)	(0.522)	(0.325)	(0.312)	(0.303)	(0.431)
Training x Class size	-0.0238**	-0.0246**	-0.0157**	-0.00447	-0.00252	0.00820
	(0.00926)	(0.0122)	(0.00756)	(0.00735)	(0.00701)	(0.0102)
Coaching	0.654*	0.251	0.769***	0.162	0.129	0.368
	(0.363)	(0.466)	(0.279)	(0.262)	(0.310)	(0.347)
Coaching x Class size	-0.00534	0.00304	-0.0131*	0.000372	5.18e-05	-0.00373
	(0.00849)	(0.0112)	(0.00666)	(0.00613)	(0.00746)	(0.00843)
Observations	254	216	253	254	245	254
R-squared	0.167	0.214	0.095	0.091	0.079	0.073

Notes: Each column represents a separate regression, estimated using equation (3). Column headings indicate the dependent variable. Standard errors are in parentheses and clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1

Figure 1: Quality of implementation in Coaching arm

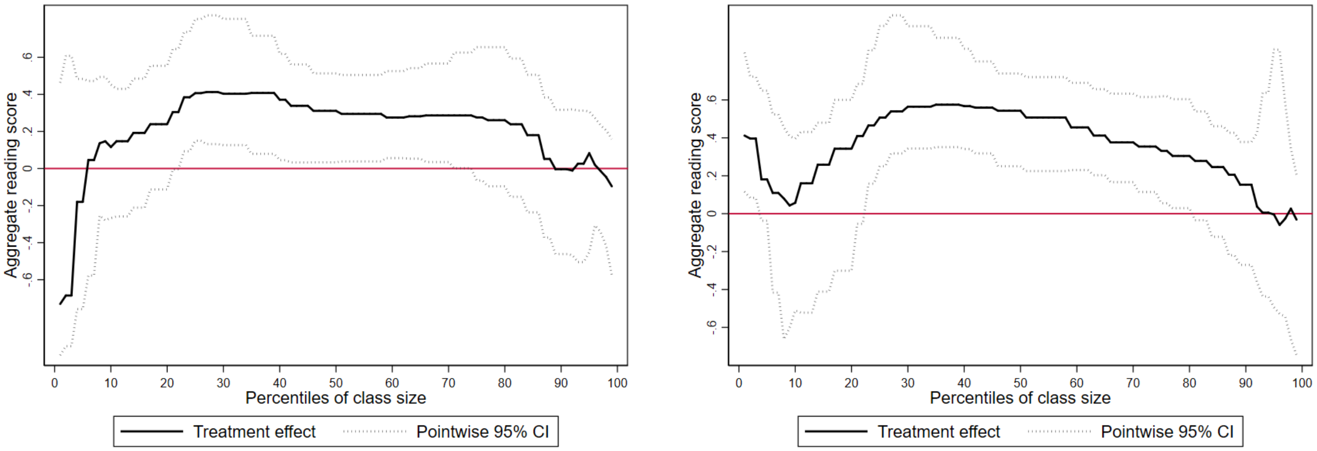


(a) Number of visits by a coach

(b) Number of group workshops

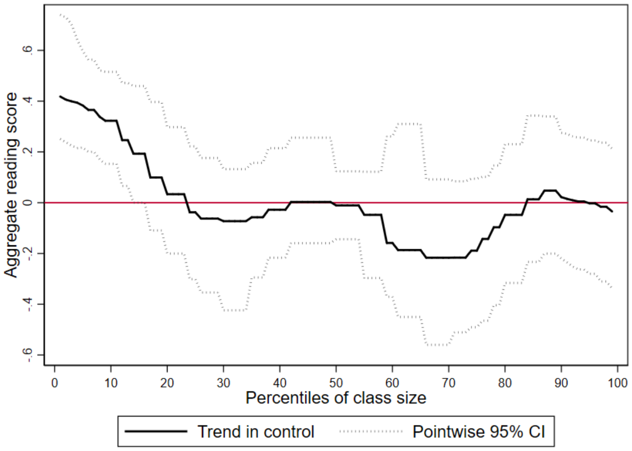
Note: Source: Class Act monitoring data for the sample of 89 teachers (from 49 schools) in the Coaching arm

Figure 2: Non-linear relationships treatment impacts and class size



(a) Training

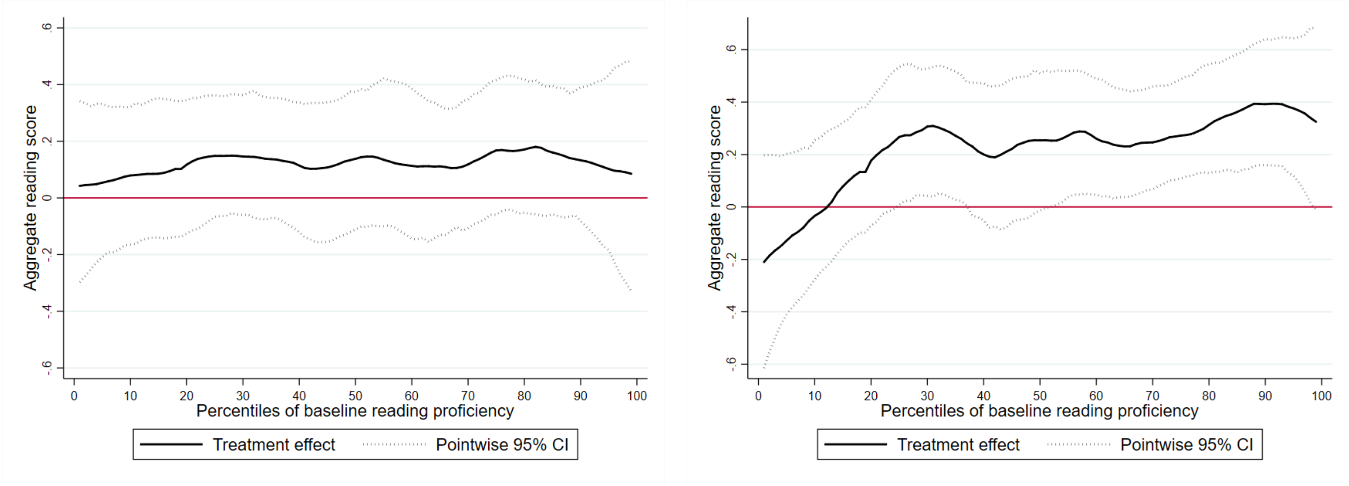
(b) Coaching



(c) Learning in control

Note: The treatment impacts in Panels (a) and (b) are constructed in four steps. First, we construct a value-added measure of reading proficiency by subtracting the predicted score from the actual score given the set of additional controls in equation 1: $\tilde{y}_{icsb1} = y_{icsb1} - \widehat{X_{isb0}'\Gamma}$. Second, we estimate a local polynomial regression of $\tilde{y}_{icsb1}$ on the percentile rank of class size separately for each treatment arm and the control. Third, we calculate the treatment impact by subtracting the fitted values of each treatment from the fitted values of the control, at each percentile of class size. Fourth, we construct pointwise 95 percent confidence intervals from a percentile bootstrap with 500 iterations, clustering at the school level and stratifying by randomization strata. Panel (c) shows the relationship between value-added learning and the percentile rank of class size in the control, estimated in steps one and two.

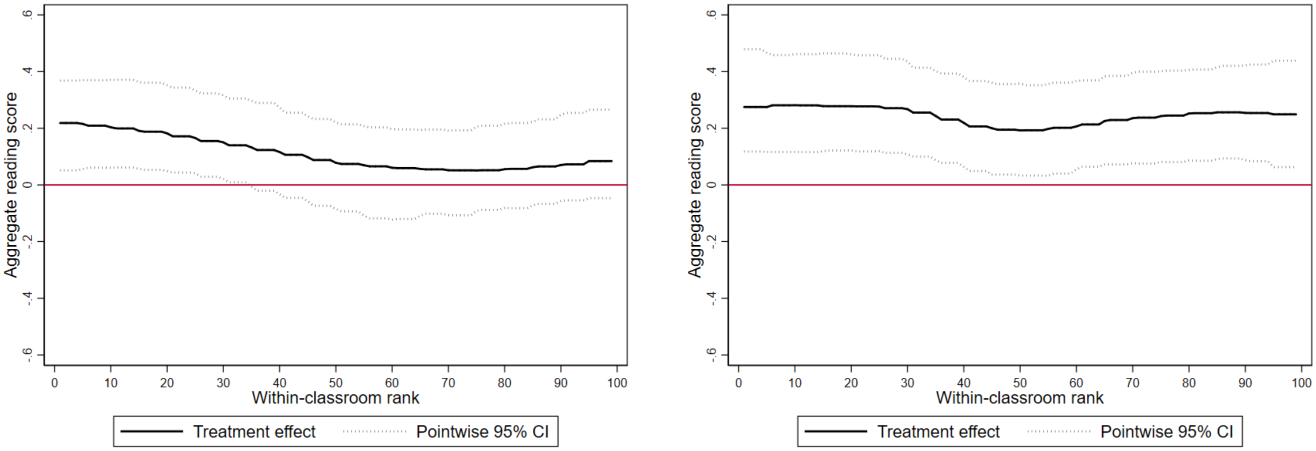
Figure 3: Non-linear relationship between treatment impacts and baseline student performance



(a) Training (b) Coaching

Note: The treatment impacts in Panels (a) and (b) are constructed in four steps. First, we construct a value-added measure of reading proficiency by subtracting the predicted score from the actual score, given the vector controls included in equation 1: $\tilde{y}_{icsb1} = y_{icsb1} - \widehat{X_{isb0}}'\Gamma$. Second, we estimate a local polynomial regression of $\tilde{y}_{icsb1}$ on the percentile rank of baseline student performance separately for each treatment arm and the control. Third, we calculate the treatment impact by subtracting the fitted values of each treatment from the fitted values of the control, at each percentile of baseline student performance. Fourth, we construct pointwise 95 percent confidence intervals from a percentile bootstrap with 500 iterations, clustering at the school level and stratifying by randomization strata.

Figure 4: Non-linear relationship between treatment impacts and baseline student within-classroom rank



(a) Training

(b) Coaching

Note: The treatment impacts in Panels (a) and (b) are constructed in four steps. First, we construct a value-added measure of reading proficiency by subtracting the predicted score from the actual score, given the vector controls included in equation 1: $\tilde{y}_{icsb1} = y_{icsb1} - \widehat{X_{isb0}'\Gamma}$. Second, we estimate a local polynomial regression of $\tilde{y}_{icsb1}$ on the within-class rank of baseline student performance separately for each treatment arm and the control. Third, we calculate the treatment impact by subtracting the fitted values of each treatment from the fitted values of the control, at each percentile of within-class rank. Fourth, we construct pointwise 95 percent confidence intervals from a percentile bootstrap with 500 iterations, clustering at the school level and stratifying by randomization strata.

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Appendix A Mediation analysis

Appendix A.1 Linear Structural Equations Model

The Linear Structural Equations Model (LSEM) compares the regression result from equations 1 and 3 with a regression that includes both the treatment dummies and the mediator, M_{cs}:

$$y_{icsb1} = \beta_0 + \beta_1(\text{Training})_s + \beta_2(\text{Coaching})_s + \beta_3 M_{cs} + X'_{isb0}\Gamma + \rho_b + \varepsilon_{icsb1}, \tag{5}$$

Under some strong assumptions, the reduction in the estimated treatment impacts, $\hat{\beta}_1$ and $\hat{\beta}_2$, between equations 1 and 5 can be interpreted as the mediation effect.

Appendix A.2 Sequential *g* estimation

The sequential *g* estimation strategy, as proposed by Acharya et al. (2016), is considered an improvement to the above since it allows one to control for all potential post-treatment confounders. (Intuitively, the mediating variable of interest, M_{cs}, could be correlated with another post-treatment variable, Z_{cs}, that is correlated with both y_{icsb1} and treatment. Not including this variable would lead to a biased estimate of the contribution of M_{cs}.)

This estimation strategy consists of three steps. The first step regresses the outcome indicator on the mediation variables of interest, treatment dummies, pre-treatment confounders, and post-treatment confounders:

$$\begin{aligned} y_{icsb1} = \beta_0 + \beta_1(\text{Training})_s + \beta_2(\text{Coaching})_s + \beta_3 M_{cs} + \beta_4(\text{Training} \times M)_{cs} \\ + \beta_5(\text{Coaching} \times M)_{cs} + \mathbf{Z_{cs}}'\Delta + X'_{isb0}\Gamma + \rho_b + \varepsilon_{icsb1}, \end{aligned} \tag{6}$$

where $\mathbf{Z_{cs}}$ is a vector of potential post-treatment confounders. We follow the recommendation of Acharya et al. (2016) and also interact the mediator with treatment. Column (2) in Table A.7 shows the result for this regression, where the mediator is our index for group-guided reading, we also include the mean indices for curriculum coverage, routine, and print-richness in the classroom as other potential post-treatment confounders.

In the second step we demediate the outcome:

$$\tilde{y}_{icsb1} = y_{icsb1} - \hat{\beta}_3 M_{cs} - \hat{\beta}_4(\text{Training} \times M)_{cs} - \hat{\beta}_5(\text{Coaching} \times M)_{cs}. \tag{7}$$

Finally, we re-run our main regression on the demediated outcome, including the pre-treatment confounders (i.e. the initial set of controls from equation 1):

$$\tilde{y}_{icsb1} = \beta_0 + \beta_1(\text{Training})_s + \beta_2(\text{Coaching})_s + X'_{isb0}\Gamma + \rho_b + \varepsilon_{icsb1}. \tag{8}$$

The treatment impacts from equation 7 can be interpreted as the Average Controlled Direct Effect (ACDE): It is what the treatment impact would have been, if the value of the mediating variable was set to zero (in our case, this is the same as setting the mediating variable equal to the mean in the control). The difference between $\hat{\beta}_1$ and $\hat{\beta}_1$ in equations 1 and 8 can therefore be interpreted as the indirect impact of the treatment through the mediator— i.e. the contribution of the mediator to the overall treatment impact.

Column (3) in Table A.7 shows the regression results from equation 8. As a comparison, column (1) shows the regression results from 1, when restricting the sample to the same set of observations as in equations 7 and 8. The reduction in treatment impact is much larger when using the sequential *g* estimator, compared to the LSEM. The reason for this is the large positive interaction between Coaching and group-guided reading.

Appendix B Further tables and figures

Table A.1 Treatment Status Regressions on Attrition Status

	(1) Attrite	(2) Age	(3) Female	(4) Reading score	(5) Teacher attrition
Attrite		0.169**	-0.0647**	-0.0175	
		(0.0678)	(0.0309)	(0.0717)	
Training	0.00605	0.0859	-0.0309	-0.204*	-0.0239
	(0.0222)	(0.0535)	(0.0241)	(0.121)	(0.0363)
Coaching	-0.0136	-0.0251	-0.0139	0.0822	-0.0234
	(0.0183)	(0.0514)	(0.0232)	(0.152)	(0.0378)
Attrition x Training		-0.0518	0.0900*	-0.0262	
		(0.102)	(0.0504)	(0.113)	
Attrition x Coaching		0.0176	0.00665	-0.103	
		(0.0961)	(0.0531)	(0.113)	
Strata fixed effects?	Yes	Yes	Yes	Yes	Yes
Observations	3,539	3,523	3,518	3,539	2,951
R-squared	0.010	0.018	0.003	0.059	0.013
Mean attrition	0.168				0.208

Notes: Each column represents a separate regression. Column headings indicate the dependent variable. "Attrite" is a dummy variable equal to one if the pupil was not surveyed at endline. "Teacher attrition" is a dummy variable equal to one if the pupil's teacher was not surveyed at endline. Standard errors are clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.2 Comparing lesson observation schools with full sample

	(1)	(2)	(3)	(4)	(5)
	Pupil reading proficiency				*Location*
	Value-added	Endline	Midline	Baseline	Rural
In sample	0.0594	-0.00586	0.0200	-0.0284	-0.250***
	(0.0724)	(0.0814)	(0.0748)	(0.119)	(0.0692)
Observations	3,148	3,148	3,337	3,539	180
R-squared	0.001	0.000	0.000	0.000	0.087
Sample mean	0.0368	0.00873	0.0304	-0.0180	0.633

Notes: Each column represents a separate regression on a dummy variable indicating whether the pupil/school is in the sample where we conducted the lesson observation. In columns (1) to (4) the data is at the individual level; in column (5) the data is at the school level. In column (1) the dependent variable is midline reading proficiency, and the regression includes the full set of controls used in Table 2. Standard errors are clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1

Table A.3 Descriptive and balance statistics - Lesson observations sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Control	*Training*		*Coaching*			
	Mean	Coef.	Std error	Coef.	Std error	Obs	R-squared
Pupil Characteristics							
Age	6.481	0.117	(0.0781)	0.0263	(0.0767)	1,194	0.021
Female	0.479	-0.0634	(0.0423)	-0.0653*	(0.0356)	1,191	0.008
Reading proficiency	0.0404	-0.244	(0.253)	0.171	(0.224)	1,198	0.157
Teacher Characteristics							
Diploma or degree	0.947	0.0451	(0.0444)	0.0559	(0.0547)	88	0.117
Age	48.92	0.108	(2.882)	0.368	(2.875)	89	0.103
Female	1	-0.0320	(0.0307)	0.00641	(0.0153)	87	0.213
Class size	42.17	-3.470	(2.692)	-7.309**	(3.057)	87	0.253
Multi-grade	0.0619	-0.0570	(0.0379)	-0.0183	(0.0382)	88	0.407
Comprehension test	0.663	-0.0663	(0.0741)	0.0198	(0.0808)	88	0.128
School characteristics							
Majority parents - highschool	0.443	-0.247	(0.179)	-0.00595	(0.170)	59	0.277
Rural	0.850	-0.0312	(0.151)	-0.144	(0.172)	60	0.239
Bottom quintile (SES)	0.463	0.0412	(0.108)	-0.0935	(0.0818)	60	0.791
Pass rate (ANA)	55.35	-0.215	(1.446)	0.773	(1.771)	60	0.542

Notes: Each row indicates a separate regression on treatment dummies controlling for strata indicators. Column one shows the control mean, columns (2) and (4) the coefficient on the two treatment dummies. Standard errors (columns (3) and (5)) are clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1

Table A.4 Results with trimmed sample for Training

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Endline				Baseline			
Training	0.116	0.117	0.113	0.124	-0.209*	-0.166	-0.116	-0.0730
	(0.0791)	(0.0792)	(0.0786)	(0.0791)	(0.118)	(0.118)	(0.119)	(0.120)
Coaching	0.242***	0.242***	0.243***	0.243***	0.0666	0.0665	0.0665	0.0665
	(0.0778)	(0.0778)	(0.0778)	(0.0776)	(0.146)	(0.146)	(0.146)	(0.145)
Percentile trimmed	0	5th	10th	15th	0	5th	10th	15th
Observations	2,951	2,918	2,878	2,843	3,539	3,499	3,445	3,399
R-squared	0.169	0.167	0.167	0.165	0.058	0.053	0.049	0.048

Notes: Each column represents a separate regression. In columns (1) to (4) the outcome variable is endline aggregate reading proficiency, and the regressions are estimated using the same set of controls as Table 3. In columns (5) to (8) the outcome variable is baseline reading proficiency, and regressions are estimated using the same set of controls as Table 1. Moving from left to right, a larger share of the sample of students in the Training arm are excluded: the bottom 5 percent, 10 percent, and 15 percent respectively, in terms of baseline aggregate reading proficiency.

Table A.5. Dynamic impacts in terms of standard deviations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	Aggregate score	Phon. awareness	Letters	Words	Non-words	Paragraph	Writing
Training	0.129	0.0919	0.0714	0.0682	0.108**	0.0925*	0.235**
	(0.0798)	(0.0716)	(0.0755)	(0.0520)	(0.0518)	(0.0518)	(0.0918)
Training x endline	-0.0124	0.0478	-0.0316	0.0201	0.00301	0.0213	-0.139*
	(0.0620)	(0.0799)	(0.0715)	(0.0696)	(0.0678)	(0.0653)	(0.0811)
Coaching	0.141*	0.222***	0.124	0.0492	0.0843*	0.0642	0.181*
	(0.0804)	(0.0725)	(0.0805)	(0.0509)	(0.0507)	(0.0500)	(0.104)
Coaching x endline	0.100	-0.0934	0.0596	0.194***	0.199***	0.199***	-0.0407
	(0.0661)	(0.0851)	(0.0923)	(0.0672)	(0.0705)	(0.0625)	(0.0915)
Endline	-0.00645	0.856***	0.633***	0.780***	0.765***	0.762***	0.0461
	(0.0429)	(0.0549)	(0.0611)	(0.0481)	(0.0445)	(0.0430)	(0.0499)
Observations	6,190	6,190	6,190	6,190	6,190	6,191	6,190
R-squared	0.171	0.251	0.232	0.296	0.275	0.284	0.124
Training x Endline=Coaching x Endline:P-value	0.0956	0.108	0.246	0.0123	0.00974	0.00883	0.322
Midline	-0.174	-1.452	0.0204	-1.002	-1.177	-1.173	-0.416
Endline	-0.0479	0.394	0.311	0.383	0.352	0.358	-0.0287

Notes. See Table 4.

Table A.6 Breakdown of variable costs by treatment arm

	Training		**Coaching**	
	Sub-total	%	Sub-total	%
Materials Provision	$ 20,985.90	18%	$ 19,799.69	12%
Transport	$ 3,687.70	3%	$ 32,268.53	20%
Accommodation and venue	$ 42,197.15	37%	$ 540.19	0%
Catering	$ 82.63	0%	$ 82.63	0%
Salary				
---Program management	$ 30,180.00	26%	$ 50,300.00	31%
---Coaches	$ -	0%	$ 55,384.62	35%
---Trainers	$ 12,038.46	11%	$ -	0%
---Motivational visits / calls	$ 3,192.31	3%	$ -	0%
---Training of trainers/coaches	$ 1,846.15	2%	$ 1,846.15	1%
Total	**$ 114,210.31**	100%	**$ 160,221.80**	100%

Table A.7. Mediation analysis using sequential g estimator

VARIABLES	(1)	(2)	(3)
Training	0.224***	0.208**	0.187**
	(0.0850)	(0.0949)	(0.0838)
Coaching	0.284***	0.122	0.0909
	(0.0861)	(0.103)	(0.0818)
Group-guided reading		0.122	
		(0.0884)	
Print-richness in classroom		-0.0883*	
		(0.0512)	
Routine		0.0382	
		(0.0724)	
Curriculum coverage		-0.0441	
		(0.0413)	
Group-guided reading x Training		0.156	
		(0.138)	
Group-guided reading x Coaching		0.318**	
		(0.142)	
Observations	2,295	2,295	2,295
R-squared	0.166	0.186	0.155

Notes. Each row represents a separate regression, including the same set of controls as Table 1, restricting the sample to students for whom we have teacher survey data. The dependent variable in columns (1) and (2) is the aggregate reading score. The dependent variable in column (3) is the demediated outcome, calculated using equations (6) and (7) in the Appendix. Standard errors are clustered at the school level. *** p<0.01, ** p<0.05, * p<0.1

Figure B.1: Timeline of study

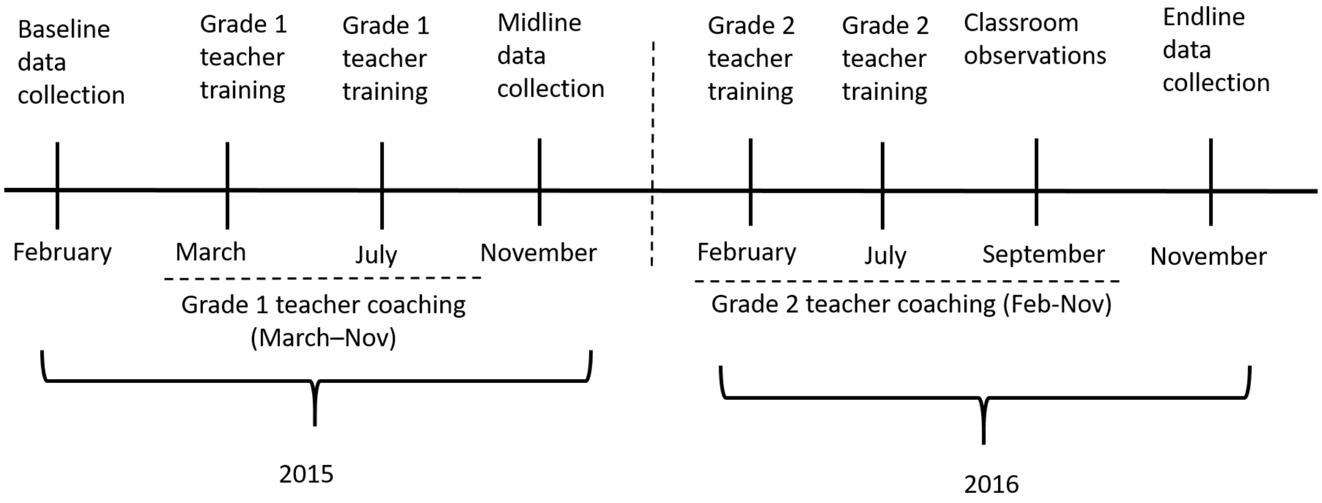
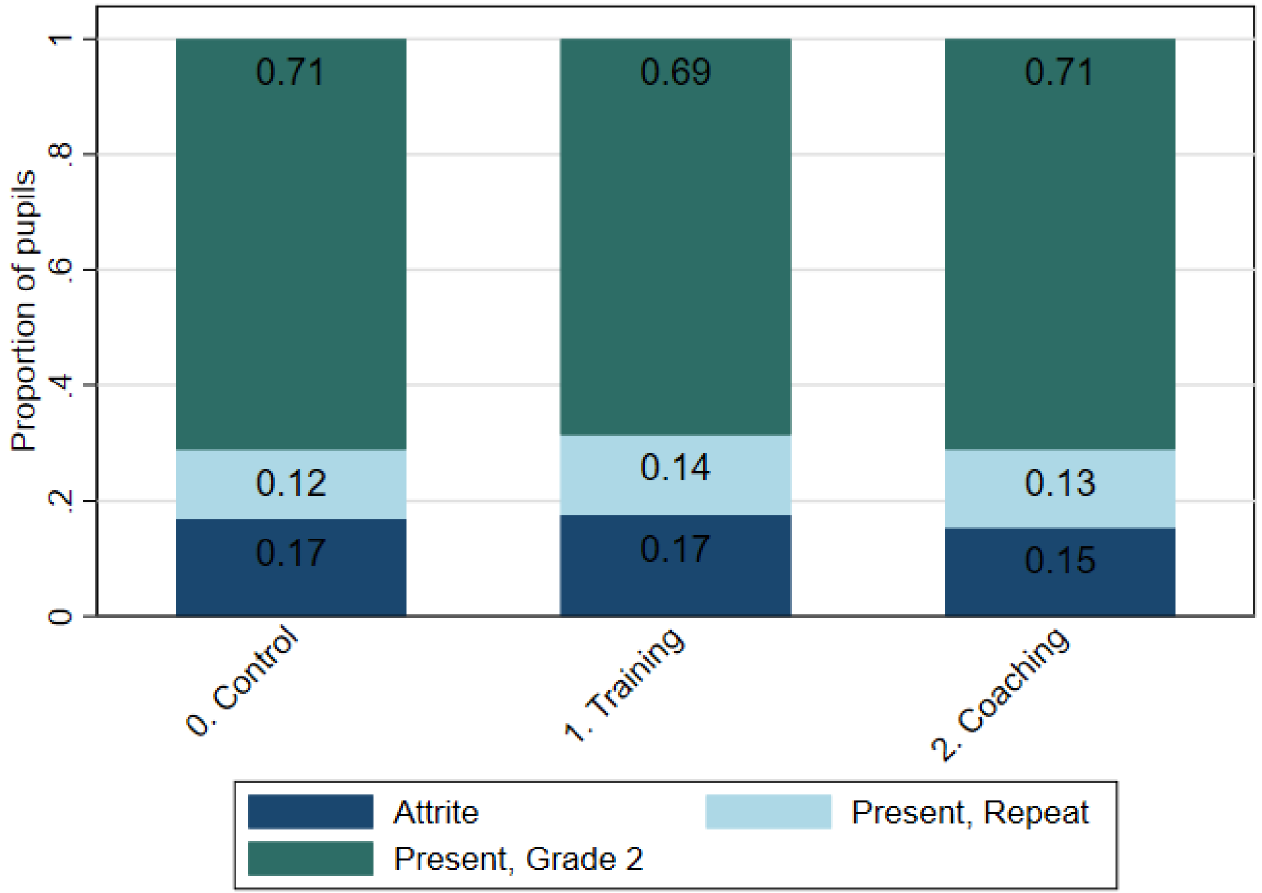
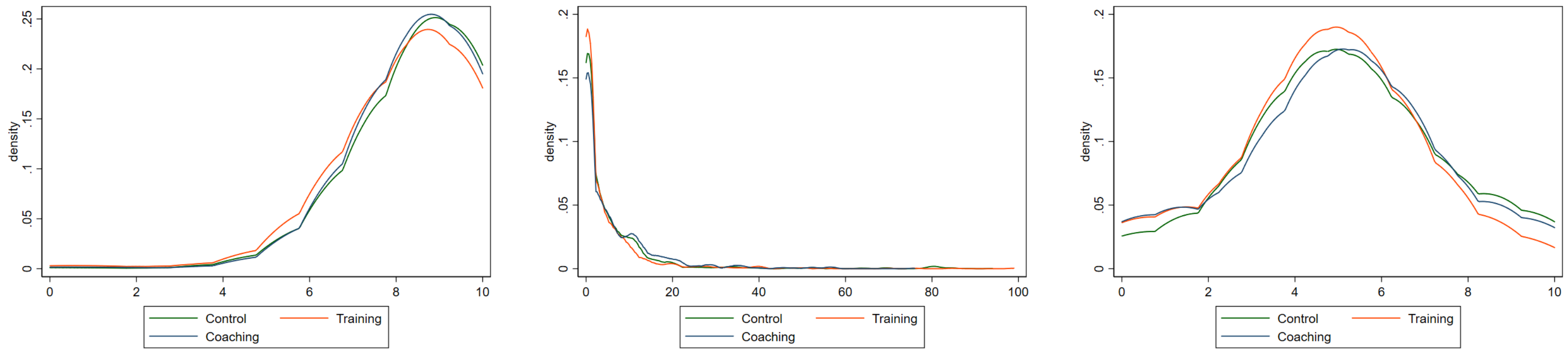


Figure B.2: Attrition and repetition rates across treatment arms



Note: The figure shows the proportion of surveyed pupils by treatment group who: (i) were not present at endline for the reading assessment; (ii) were present, but are repeating grade one; (iii) were present and are in grade two

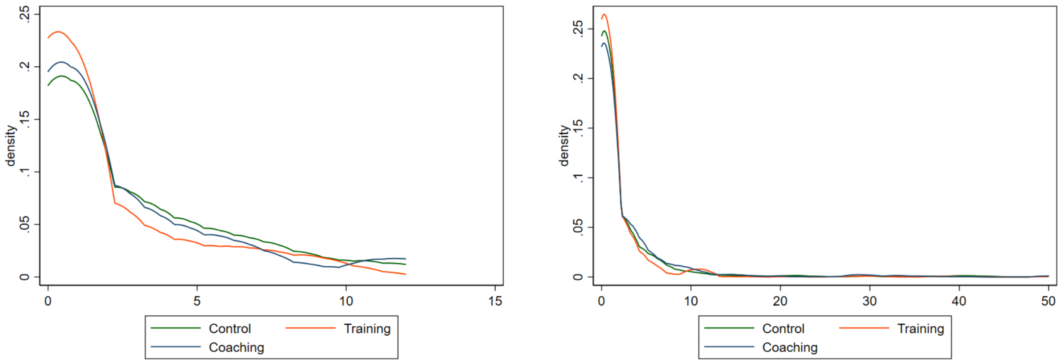
Figure B.3: Baseline distribution of reading proficiency scores



(a) Picture comprehension test

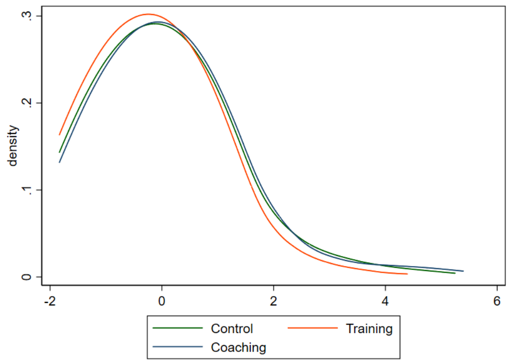
(b) Letter recognition

(c) Digit span test



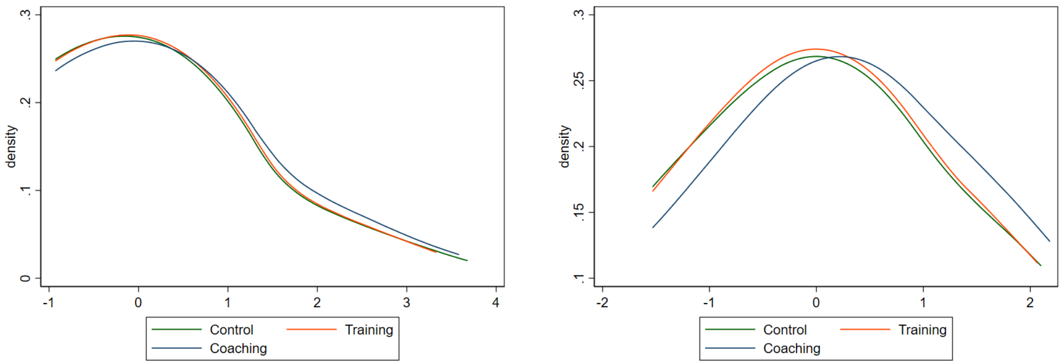
(d) Phonological awareness

(e) Words correct



(f) Mean index

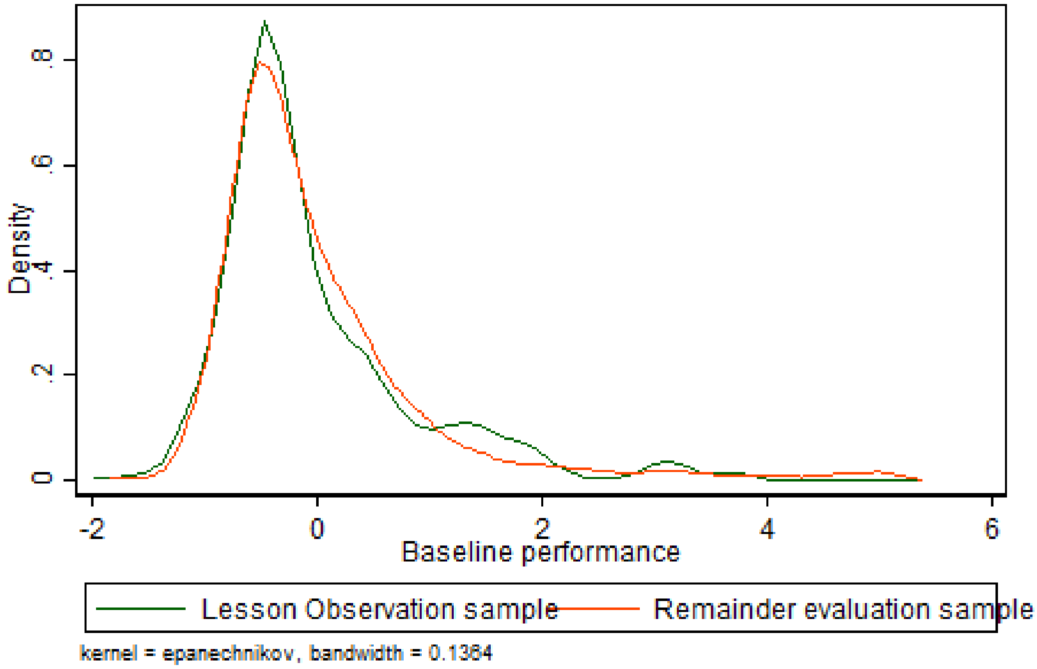
Figure B.4: Post-intervention distribution of aggregate reading proficiency



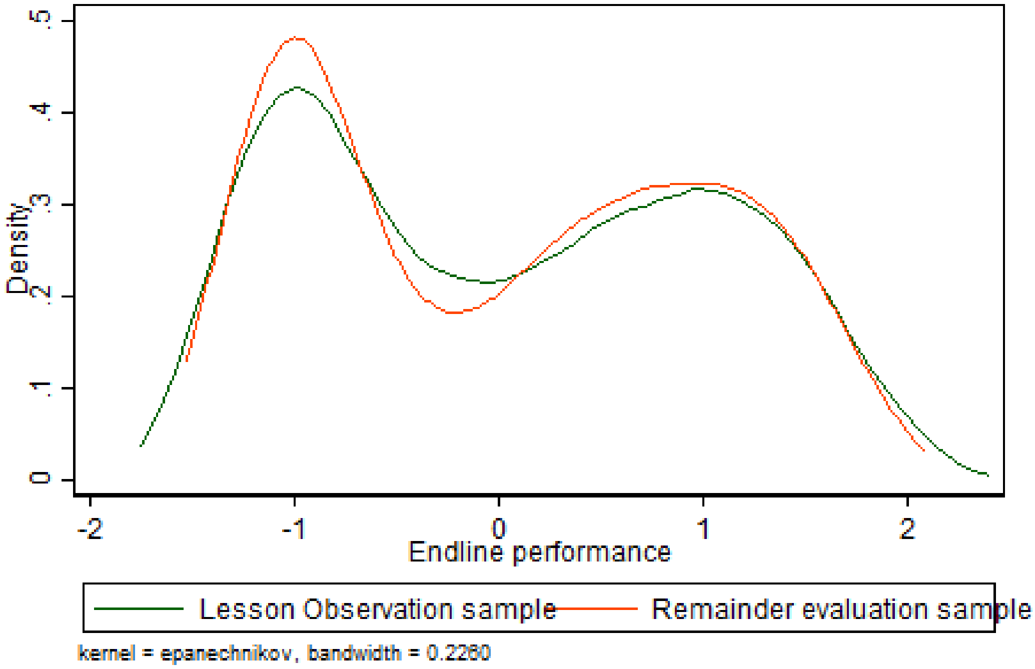
(a) Midline

(b) Endline

Figure B.5: Comparing the distribution of pupil performance between lesson observation sample and the remaining sample

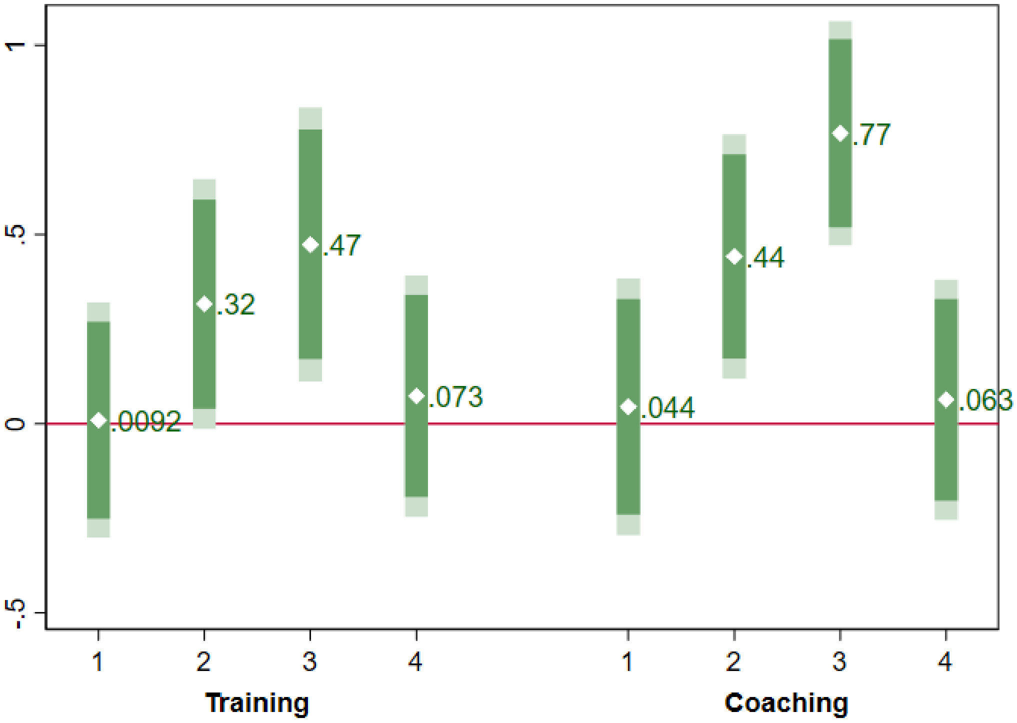


(a) Baseline pupil performance

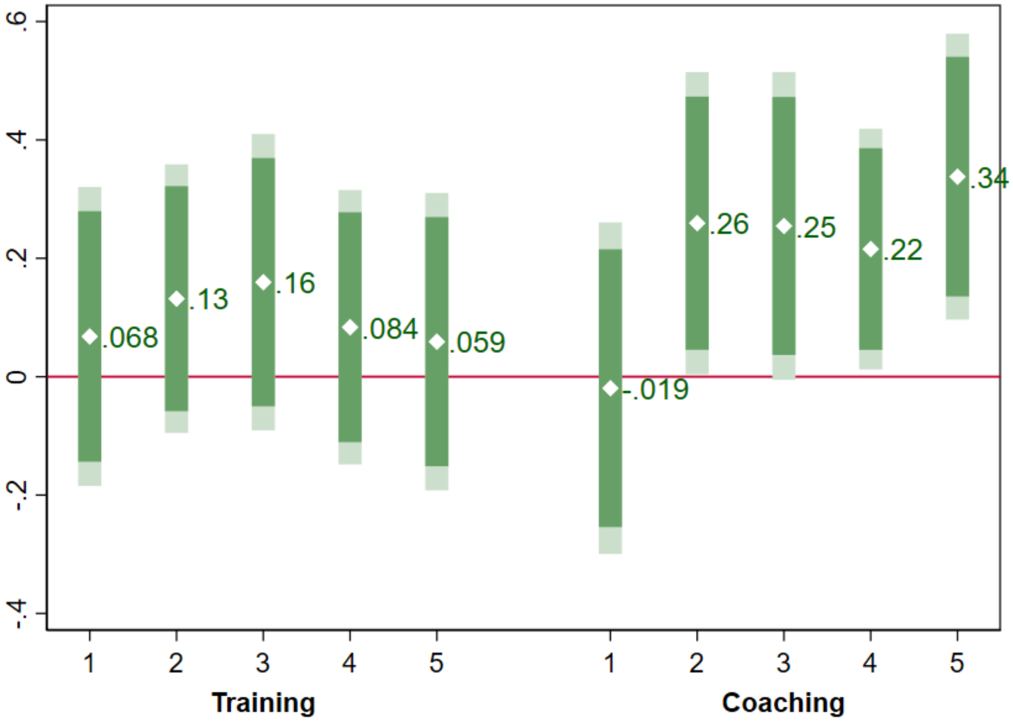


(b) Endline pupil performance

Figure B.6: Heterogeneous treatment impacts



(a) By quartiles of class size



(b) By quintiles of baseline pupil performance