Changing trajectories of learning and development: experimental evidence from the Quality Preschool for Ghana interventions

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Project   Quality Preschool for Ghana View project

Changing trajectories of learning and development:experimental evidence from the Quality Preschool for Ghana interventions

Sharon Wolf and Morgan Peele

Abstract: We examined how exposure to two intervention programmes designed to improve the quality of pre-primary education in Ghana—the Quality Preschool for Ghana project—impacted children's rate of growth in academic (literacy and numeracy) and non-academic skills (social–emotional and executive function) across two school years. This cluster-randomised trial included 240 schools (N = 3,345 children, M_{age} = 5.2 at baseline) randomly assigned to one of three conditions: teacher training (TT), teacher training plus parental-awareness meetings (TTPA), and control. We found some evidence that the interventions altered children's rate of growth in academic and non-academic skills for the full sample, and one unexpected finding: TTPA had negative impacts on growth in numeracy skills. When examined by grade level and gender, TT improved trajectories of younger children, and the negative effects of TTPA on numeracy were driven by boys. Implications are discussed in the context of global early childhood education policy, and teacher professional development and parental engagement programmes.

Keywords: Early childhood education, cluster-randomised trial, learning, Ghana, sub-Saharan Africa, early childhood development.

1. INTRODUCTION

Countries across the world, including in sub-Saharan Africa (SSA), have made tremendous strides in increasing children's access to primary schooling. Despite being in school, however, a large proportion of children fail to learn functional literacy skills in the first three years of primary school (Gove & Cvelich 2011, Uwezo 2013). This 'learning crisis' (World Bank 2018) has drawn increased focus on improving the need to improve educational quality and children's readiness for school. As a result, many governments around the world are increasing investments in pre-primary education as a way to promote children's learning and development so that they are ready to learn. Yet similar concerns about the quality of pre-primary education have been raised (Yoshikawa *et al.* 2018), suggesting that expansion in pre-primary education may not be reaching its potential to improve young children's school readiness.

The potential for early childhood education (ECE) to enhance children's development may be large in parts of the world where children face extreme levels of risk. Compared to other regions, SSA has the largest proportion of young children experiencing extreme poverty (66 per cent (Black *et al.* 2017)), as well as the largest number and proportion of 3- and 4-year-olds (29.4 million; 44 per cent) failing to meet cognitive and SE milestones (McCoy *et al.* 2016). At the same time, SSA has lower ECE enrolment rates, at around 18 per cent, compared to other regions (McCoy *et al.* 2018). Given extremely low learning levels in primary school across SSA countries (Sandefeur 2016), ECE may be one approach to boost children's school readiness and ultimately improve learning trajectories.

As children transition to school, they draw on a multitude of social, emotional, behavioural, and academic competencies. These early learning skills, or 'school readiness skills', are crucial for successful transition and adaptation to school (for example, Blair & Razza 2007, McClelland *et al.* 2000). Academic and non-academic competencies are interconnected, with non-academic skills, such as EF and SE skills, supporting children's abilities to learn academic content in the classroom. As more children enrol in pre-primary education in LMICs, it will be important to understand how they acquire both academic and non-academic skills, and the role of quality pre-primary education in improving the trajectories of skills acquisition.

In this study, we report on longitudinal impacts of the Quality Preschool for Ghana project (Wolf *et al.* 2019a, 2019b), an evaluation of two intervention programmes designed to improve the quality of pre-primary education in Ghana. We evaluate programme impacts on the growth of children's literacy, numeracy, SE, and EF skills by modelling the linear slopes (rate of change) of children with three waves of data collected over the course of two school years. We also examine whether programme impacts on growth differ by grade level (that is, for children over two

years of pre-primary school over the course of the study versus children in the second year of pre-primary school and first year of primary school over the course of the study), and for boys and girls.

1.1 School readiness skills

School readiness can be defined broadly as an outcome of the early years that covers multiple dimensions of development, including early academic skills, SE and EF skills, and aspects of physical health (Snow & Van Hemel 2008, UNESCO 2013). Children's school readiness skills develop rapidly during the preschool years due to children's increasing neurodevelopmental capacity for higher order thinking (Shonkoff & Phillips 2000, Zelazo & Carlson 2012), as well as increased environmental demands (for example, in the classroom if children are enrolled in quality pre-primary).

Children's literacy and numeracy skills at school entry are powerful predictors for later academic achievement because they form the foundation for acquiring higher level academic skills (Duncan *et al.* 2007). Literacy and numeracy are domain-specific skills that children develop through a cumulative and iterative process, as children are continuously refining and building on previous knowledge in order to learn new and more advanced material (Cunha *et al.* 2010). This process highlights the need to master foundational content early in their schooling, and provides some insight into why children who do not acquire basic literacy skills before grade three have a much harder time learning to read (Jordan *et al.* 2009).

In contrast, SE and EF skills are domain-general, non-academic constructs. A growing body of research has also identified non-academic skills as core to young children's school readiness (Blair 2002, Duncan *et al.* 2007, Raver 2003). In particular, EF skills include the higher order cognitive processes that help children control impulses, maintain and shift attention, and manipulate information in working memory (Blair 2002, Miyake *et al.* 2000). SE skills generally include the abilities to recognise and manage emotions, appreciate the perspectives of others, constructively handle interpersonal conflicts, make responsible decisions, and form positive relationships (CASEL 2017, Ellis *et al.* 1997). Such prosocial skills are considered important in fostering positive peer and teacher relationships, emotional competencies, and social problem-solving skills (for example, Coolahan *et al.* 2000, Denham & Burton 2003, Greenberg *et al.* 1991, Ladd *et al.* 2000).

There is consistent evidence in high-income countries that EF is positively related to children's academic skills during the transition to school (Blair & Razza 2007, Brock *et al.* 2009, Bull *et al.* 2011, Matthews *et al.* 2009, McClelland *et al.* 2007, Ponitz *et al.* 2009). Increasing evidence in low- and middle-income countries (LMICs)

shows that EF skills are correlated to learning both cross-sectionally (for example, Obradović *et al.* 2019, Raikes *et al.* 2019, Willoughby *et al.* 2019, Wolf *et al.* 2017) and longitudinally (Wolf & McCoy 2019). There is also some evidence, but far less, that SE skills support learning outcomes in the transition to kindergarten (Arnold *et al.* 2012, Curby *et al.* 2015, Graziano *et al.* 2007, Izard *et al.* 2001, McKown *et al.* 2016).

1.2 Impacts of pre-primary education in developing countries on school readiness skills

The preschool period is one of rapid development that underlies the acquisition of academic and non-academic skills (Shonkoff & Phillips 2000). Over the past fifteen years, there has been a rapid expansion of ECE services around the world (UNESCO 2015), providing a growing platform through which children's school readiness may be enhanced. Access and participation rates in ECE are lower in LMICs than in high-income countries (HICs), ranging from an average of 17.9 per cent of 3- and 4-year-olds enrolled in ECE programmes in SSA to 61.7 per cent in Latin America and the Caribbean (McCoy *et al.* 2018). Despite clear evidence that more children are participating in ECE, research on the quality of these programmes and their effects on children's development is less established, though one study suggests that enrolment in poor-quality programmes can be detrimental to children's development (Berlinski *et al.* 2009).

The vast majority of experimental studies on ECE impacts and the role of ECE quality have been conducted in the United States. However, there are a small and increasing number of studies in LMICs, mostly focused on short-run impacts, typically within a year of programme initiation. Araujo *et al.* (2016) randomly assigned Ecuadorian children to kindergarten teachers across 204 schools. A one-standard-deviation increase in classroom quality (total CLASS scores) predicted increases in children's language, maths, and EF of 0.11, 0.11, and 0.07 standard deviations over one school year, respectively. In Bangladesh, children exposed to a high-quality preschool programme outperformed a control group in verbal and non-verbal reasoning, as well as school readiness, by the end of that school year (Aboud 2006). Finally, an evaluation is ongoing of the Tayari programme in Kenya, which implemented curriculum-aligned instructional materials and teacher training and support in pre-primary schools. Preliminary results show the programme had short-term impacts on children's global school readiness skills, but negative impacts on literacy and numeracy skills the following school year when children were in primary school (Nderu *et al.* 2019).

Very little is known about learning trajectories across the different domains of school readiness skills in LMICs. Most studies have not examined rates of growth over time in the acquisition of skills, particularly in the context of intervention research. In this study, we were interested in identifying whether exposure to higher

quality pre-primary education changed developmental levels or rates of change over time in school readiness skills across two school years.

1.3 The Quality Preschool for Ghana interventions

In 2004, the Government of Ghana adopted the National Early Childhood Care and Development Policy. Among other components, this policy highlighted access to quality pre-primary education as a central platform for improving early childhood development and school readiness, as well as for reducing inequalities in educational outcomes. In 2007, the government added two years of pre-primary education to the universal basic education system, called kindergarten 1 (KG1; for 4-year-olds) and kindergarten 2 (KG2; for 5-year-olds). Ghana now has one of the highest pre-primary enrolment rates on the continent at 75 per cent net enrolment in 2015–2016 (Ghana Ministry of Education 2016). Despite success in increasing access to pre-primary school, a 2012 government Kindergarten Situational Report concluded that the quality of the KG sector was poor and that teachers had not been properly trained on the curriculum established in 2004. The report concluded that teacher training was a top education policy priority. A secondary priority was to engage parents in their child's KG education at home and in school as a platform to increase parent engagement in education more generally. It is in this context that the Quality Preschool for Ghana (QP4G) project took place.

1.3.1 The programmes

The goal of QP4G was to develop and rigorously evaluate a scalable model of transformational teacher training to provide high-quality ECE services to children and to test the benefits of engaging parents via an awareness campaign designed to align parental expectations with these practices. The primary component was a *teacher training and coaching* programme designed to improve classroom quality and children's school readiness skills. The main training was five days at the start of the school year, followed by two refresher trainings implemented at the start of the second and third terms. The trainings were implemented by professional teacher trainers at the National Nursery Teacher Training Centre in Accra, a teacher-training facility affiliated with the Ministry of Education that provides ECE certification courses for teachers. The content focused on integrating play- and activity-based, child-centred teaching practices into teaching instructional content, positive classroom management, and assessment and planning. Teachers also received coaching visits two times per term from the district government ECE coordinator.

The *parental-awareness meetings* consisted of three meetings administered through school parent–teacher associations (PTAs) over the course of the school year. They

were open to all parents with KG children in the school and administered by the same trained district government ECE coordinators. Each meeting consisted of a video (the content was developed for the intervention) followed by a discussion led by the district coordinator. The video themes were (1) the importance of play-based learning, (2) parents' role in child learning, and (3) encouraging parent–teacher and parent–school communication. The aim was to increase parental involvement with their children's education at home and in school and increase parent–teacher communication. The interventions are described in more detail in Wolf (2019a).

Schools were randomly assigned to either receive the teacher training and coaching programme (TT condition), TT plus the parental awareness meetings (TTPA condition), or a control group.

1.3.2 Findings to date

Two previous studies have reported the results on point-in-time estimates of the programme impacts during the intervention year and one year later. These studies showed that during the intervention year, both TT and TTPA statistically significantly ($p < 0.05$) improved classroom quality, increasing the number of activities and positive behaviour management in the QP4G classrooms (effect size (e.s.) = 0.54 and 0.60, respectively), improving classroom emotional support and behaviour management (e.s. = 0.62 and 0.64, respectively), and improving support for student expression in the TT treatment alone (e.s.= 0.48).

Regarding child outcomes, the TT condition improved children's overall school readiness skills (e.s. = 0.13). When analysed by individual domains, statistically significant improvements were observed in literacy (e.s. = 0.11), numeracy (e.s. = 0.011), and SE skills (e.s. = 0.18) during the treatment year (Wolf et al. 2019a). One year later, there were persistent impacts on SE skills alone (e.s. = .13), with marginally statistically significant impacts on EF (e.s. = 0.11, $p < 0.10$ (Wolf et al. 2019a)).

When implemented with the parental-awareness meetings, the TTPA condition showed no improvements on any school readiness skills, suggesting that adding the parental-awareness component counteracted the positive gains from the TT condition implemented alone. Subgroup analyses revealed that one year later, the counteracting negative impacts were restricted to children in households with a non-literate male head (Wolf et al. 2019b), suggesting that parents who had less education were more likely to disagree with the messages of the training and push back in counterproductive ways.

1.2 The current study

The current study extends the previous analyses of the QP4G programmes by examining treatment impacts on *learning trajectories* over the two years of previously

reported findings. By focusing on key academic and non-academic skill development during and after exposure to higher quality ECE, we extend the literature on how pre-primary education impacts child development and school readiness in SSA. In addition, we examine whether impacts on trajectories vary by two child characteristics: grade level (a proxy for age and stage of schooling) and sex (boys versus girls). The two-year period covers different stages of schooling for younger children (in KG1 at programme initiation) and older children (in KG2 at programme initiation). Children in KG1 at programme initiation continued in pre-primary education during the second year of the study (now in KG2), while the older children in KG2 at programme initiation transition to the first year of primary school during the second year of the study. The findings lay the groundwork for future longitudinal impact evaluations of educational programmes to consider rate of learning/growth as an additional way to examine ECE programme impacts and longer term persistence.

2. METHOD

2.1 Participants and protocol

The research design was a cluster randomised trial, where schools were randomly assigned to one of three treatment arms noted above: (a) TT: 82 schools, (b) TTPA: 79 schools, and (c) control group: 79 schools. The implementation and first-year evaluation of the QP4G intervention occurred between September 2015 and June 2016. All data presented in the initial study were collected in September–October 2015 (baseline), May–June 2016 (follow-up 1), and May–June 2017 (follow-up 2). The school year in Ghana begins in September and ends in July.

Six of the sixteen districts in the Greater Accra region were selected for the study. These districts were rated as the most disadvantaged districts in the 2014 UNICEF District League Table (a social accountability index that ranks regions and districts based on development and delivery of key basic services, including education, health, sanitation, and governance) (UNICEF 2015). Randomisation was stratified by district and sector (private and public) to TT condition, TTPA condition, or control.

The trial was registered in the American Economic Association registry for randomised controlled trials (RCT ID: AEARCTR-0000704). However, examining impacts on trajectories of growth was not specified in the pre-analysis plan. Thus, we consider this an exploratory study.

2.2 Sampling and data collection procedures

2.2.1 School sample

Schools were identified using the Ghana Education Service Educational Management Information System (GES-EMIS) database. Eligible schools had to be registered with the government and have at least one KG class. Schools were then randomly sampled, stratified by district, and within district by public and private schools. Every public school was sampled because there were fewer than 120 public schools across the six districts. Private schools (490 total) were sampled within districts in proportion to the total number of private schools in each district relative to the total for all districts. All KG teachers in the schools were invited to participate in the training. Schools had one to five KG teachers, with most schools having two KG teachers. Thirty-six schools only had one KG teacher, and in this case the one teacher was sampled. If there were more than two KG teachers in the school, two teachers were randomly sampled per school for the evaluation (one from KG1 and one from KG2). The final sample included 444 classrooms in 240 schools.

2.2.2 Child sample

Class rosters for KG classrooms were collected. A target of fifteen children (eight from KG1 and seven from KG2) were randomly selected from each roster to participate in direct assessments. If a school had fewer than fiteen children enrolled across both classrooms, all children were selected. Assessors also randomly selected up to ten additional children on the initial visit (a 'reserve' list). If a selected child from the first fifteen was not in school on the day of the evaluation, assessors returned up to two times to assess the child. If the child was still not present on the third visit, a child from the reserve list replaced that child. For schools with only one KG classroom, fifteen children were randomly sampled from the classroom. At baseline, the total sample of children was 3,435 children, with an average of 14.3 children per school (range = 4–15).

Table 1 presents descriptive statistics of the schools and children in the sample by treatment group status, and a sample flow chart is presented in Figure 1.

2.2.3 Data collection procedures

Children's school readiness skills were assessed directly in their schools following verbal consent. QP4G assessors worked with head teachers to designate a few quiet, private spaces on the school grounds to conduct the assessments. These spaces were out of sight of other children.
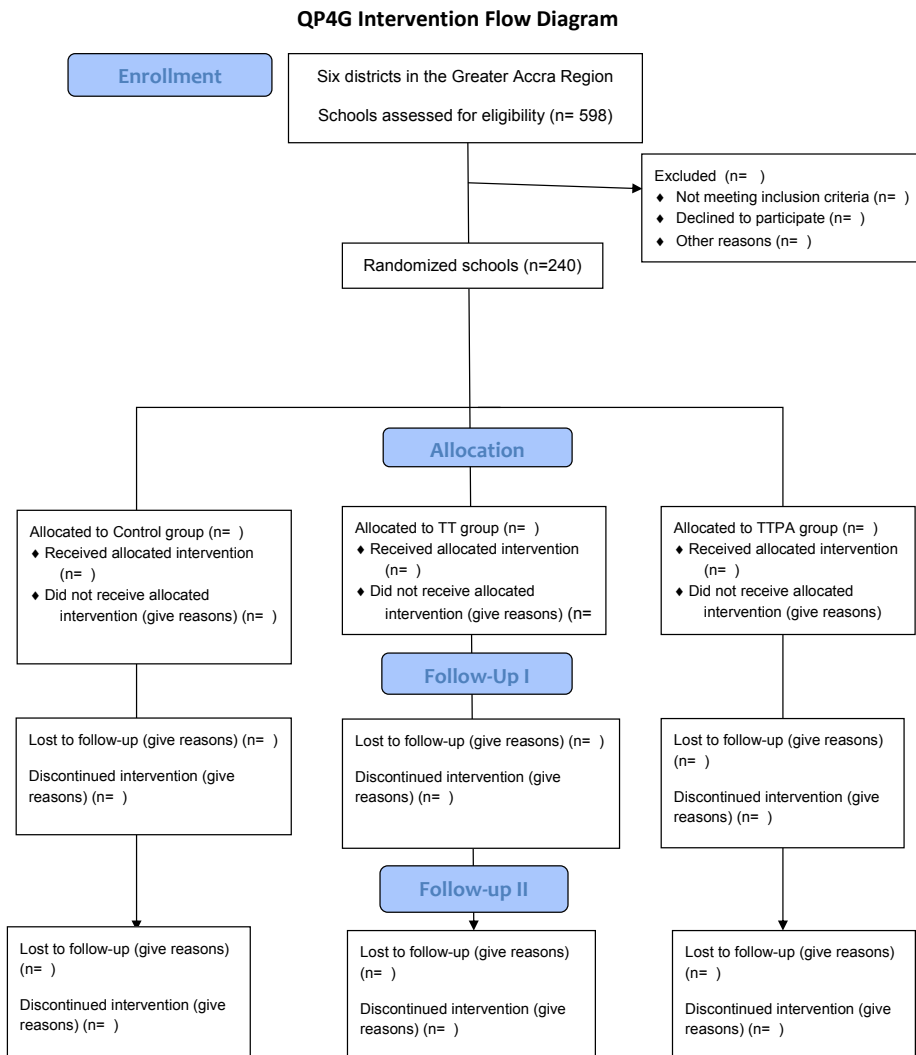
QP4G Intervention Flow Diagram

Figure 1. Sample flow chart.

2.2.4 Assessment development and adaptation

Extensive work was done to ensure that all measures were contextually appropriate. The child assessment tool was translated into three local languages (Twi, Ewe, and Ga). Surveys were translated and then back-translated by different persons to check for accuracy. Any discrepancies were discussed and addressed. QP4G assessors spent several minutes chatting and playing games with children to make them comfortable before beginning the assessment. As schools in this sample reported using a mixture of English and local language for instruction, part of this initial introduction was

Table 1. School and child characteristics, by treatment status.

	Control	TT	TTPA	*F*-statistic	*p*-value
Baseline school characteristics			mean or %		
Private school status	**55.7%**	**56.1%**	**53.2%**	**0.08**	**0.923**
Number of years school has been established	23	23	19	0.95	0.389
School has written rules/regulations for staff	38.5%	48.8%	35.9%	1.52	0.222
Total number of KG children in school	54	63	60	0.64	0.529
Total number of KG teachers on the payroll	2	2.3	2.2	0.98	0.376
Main language of instruction in KG1					
English only	10.5%	13.5%	7.5%	0.68	0.509
Mother tongue only	4.5%	1.4%	1.5%	0.90	0.407
Mixture of English and mother tongue	85.1%	85.1%	91.0%	0.70	0.496
Baseline sample size (total = 240)	79	82	79		
Child characteristics					
Female	50.0%	48.5%	49.0%	0.27	0.764
Age (baseline)	5.25	5.17	5.25	1.02	0.361
KG1 (vs. KG2)	53.5%	52.1%	52.6%	0.24	0.789
Early literacy (mean % correct)					
Time 1	43.9%	45.0%	45.8%	1.97	0.140
Time 2	60.8%	63.1%	61.7%	3.44	0.032
Time 3	70.0%	71.8%	70.4%	2.54	0.079
Early numeracy (mean % correct)					
Time 1	44.1%	45.4%	46.1%	2.34	0.097
Time 2	56.6%	58.8%	57.9%	3.27	0.038
Time 3	66.6%	67.2%	66.2%	1.00	0.368
Social–emotional (mean % correct)					
Time 1	41.4%	42.1%	43.2%	2.04	0.130
Time 2	44.9%	48.4%	48.0%	9.39	0.000
Time 3	57.7%	59.8%	58.4%	3.73	0.024
Executive function (mean % correct)					
Time 1	56.5%	55.9%	54.8%	1.02	0.361
Time 2	57.9%	59.7%	59.2%	2.57	0.077
Time 3	63.7%	64.4%	63.2%	1.36	0.256
Baseline sample size (total = 3,435)	1,088	1,180	1,167		

Notes. Baseline / Time 1 was collected in September–October 2015; Time 2 in May–June 2016; Time 3 in May–June 2017.

intended to help the assessor to gauge children's linguistic preferences. Assessors then administered the assessment in the language he/she deemed most appropriate for the child. At baseline, this included: Twi/Fanti only (39.0 per cent), Ewe only (1.3 per cent), Ga only (5.0 per cent), English only (37.9 per cent), and mixed English and local language (16.9 per cent).

2.3 Measures

2.3.1 Child school readiness skills

Four domains of child outcomes were directly assessed using the International Development and Early Learning Assessment (IDELA) (Pisani *et al.* 2018): early literacy, early numeracy, SE, and EF skills. Recent studies have assessed the psychometric properties and factor structure of the IDELA (Wolf *et al.* 2017), as well as partial measurement invariance across five countries (Halpin *et al.* 2019). Pisani *et al.* (2018) provide an overview of the development of the IDELA items.

Early numeracy included thirty-nine items grouped into eight constructs: number knowledge, basic addition and subtraction, one-to-one correspondence, shape identification, sorting abilities based on colour and shape, size and length differentiation, and completion of a simple puzzle ($\alpha = 0.72$ at baseline and follow-up 2). For example, the assessor showed the child a picture with six shapes and asked the child to identify a circle.

Early literacy included thirty-eight items grouped into six constructs: print awareness, letter knowledge, phonological awareness, oral comprehension, emergent writing, and expressive vocabulary ($\alpha = 0.74$, 0.72, and 0.88 at the three waves, respectively). For example, the child was asked to identify words that begin with the same sound (for example, 'Here is my friend mouse. Mouse starts with /m/. What other word starts with /m/? Cow, doll, milk?') in order to evaluate phonological awareness.

Executive function was evaluated using ten items grouped into working memory (that is, forward-digit span) and impulse control (that is, head–toes task, adapted from McClelland *et al.* (2014) as described in Pisani *et al.* (2018)). For the forward-digit span, the assessor read aloud five-digit sequences (beginning with two digits and increasing up to six digits). The child was then asked to repeat the digit span. For the head–toes task, the assessor asked the child to touch his/her toes when the assessor touched his/her head, and vice versa, in a series of five items. (Because there are only two subtasks, rather than present internal consistency we present the correlation between the two subtasks; $r = 0.21$, 0.25, and 0.22 at the three waves, respectively.) *Social–emotional* skills included fourteen items grouped into five constructs: self-awareness, emotion identification, perspective taking and empathy, friendship, and conflict and problem solving ($\alpha = 0.69$, 0.69, and 0.67 at the three waves, respectively). For example, the child was asked to imagine a scenario where they are playing with a toy and another child wants to play with the same toy. The child was then asked what he/she would do to resolve that conflict. 'Correct' answers in the Ghanaian context (as agreed upon by the assessors during training) included talking to the child, taking turns, sharing, and getting another toy.

2.4 Analytic plan

Baseline equivalency across school, teacher, and child characteristics was established and is described in detail in Wolf *et al.* (2019a). The results confirm that randomisation successfully yielded three groups equivalent on observed characteristics.

2.4.1 Missing data imputation

We used multiple imputation (with Stata's 'ice' command) to address missing data on all missing variables, including dependent variables, using three rounds of data collection (baseline and follow-up, as well as a second round of follow-up data). While the data are not missing completely at random (MCAR), if variables that strongly predict attrition are incorporated into the missing data strategy, the plausibility of a missing at random (MAR) assumption increases (Young & Johnson 2015). In other words, including a large set of covariates in estimating multiple chains of models, including those that predict differential attrition, the assumptions of MAR have been shown to be robust. Our imputation approach meets the standards of the What Works Clearinghouse Version 4.0 Standards Handbook (IES 2017).

We conducted the imputation in two steps. First, using a rich set of teacher demographic and background variables, outcome scores for professional well-being and classroom quality across all waves, and treatment status indicators, we imputed twenty teacher-level data sets. Second, we randomly selected ten of these teacher data sets. We merged each individual data set with the children outcomes data and basic children demographic characteristics from all three waves of data. For each of the ten teacher data sets, we imputed ten child data sets, resulting in 100 child-level data sets.

2.4.2 Growth curve models

A series of linear growth curve models was estimated to examine the relationships between the treatment status and child outcomes over time, along with the set of covariates identified above. This multilevel approach was deemed most appropriate given the nested nature of the data, with multiple observations/time (L1) nested within children (L2), who were nested within classrooms (L3), which were nested within schools (L4). We modelled only linear growth because this was the most reliable approach with three time points of data, as opposed to quadratic or spline patterns of growth that require at least four time points to reliably estimate (Singer & Willett 2003).

Growth curves are characterised by a fixed part that contains average effects for the intercept and slope (rate of change over time), and a random part that contains individual differences (variance) in the intercept, slope, and the within-person residual. To examine the progression of students' outcomes across the intervention, growth

curve models were run that assessed the intercept at the third time point (T3), as well as change across time points. Therefore, positive effects on the intercept reflect higher levels of student outcomes at T3, while negative ones reflect lower levels at T3. Those covariates with positive effects on the slope terms are associated with steeper increases in student outcomes over time. Those covariates with negative effects on the slopes are associated with more gradual increases or decreases over time.

To examine intervention impacts on growth, we include a cross-lagged interaction term between a school-level dummy variable indicating whether schools were randomly assigned at baseline to TT or TTPA (L4; reference is the control group) and time (L1). We ran separate models for each of the four domain-specific skills. All of these models included the treatment status dummies and all of the covariates, with the intercept at T3. The coefficients in these models represents average values for each outcome across the sample. Since the effect of the treatment on students' outcomes at T3 have already been previously reported (Wolf *et al.* 2019b), we focused on interpreting the effect of the treatment on the rate of growth in children's skills over time.

Finally, we ran each of the models stratified by KG level at programme initiation (KG1 and KG2) and by sex of the child (boys and girls). First, we ran a series of three-way interactions (that is, KG level, treatment status, and time) and used post-estimation Wald tests to assess whether there were significant differences between the coefficients in the interactions (tables of these Wald tests are shown in Table A1 and Table A2 in the Appendix). We then ran the models separately for each subgroup.

3. RESULTS

3.1 Impacts on growth of academic skills

The first two columns in Table 2 display the estimates for the two academic outcomes, literacy and numeracy. The third and fourth rows display the impact estimates of QP4G at T3 (intercept), and the fifth and sixth rows display impact estimates on rate of change over time (slope), the second of which is our main parameter of interest. Similar to our previously reported impacts in year 2 (Wolf *et al.* 2019a), there were no statistically significant impacts on either academic outcome at T3. An examination of the impacts on rate of growth, however, revealed that there were small negative impacts of the TTPA condition on the rate of change in children's early numeracy skills ($b = -0.009$, SE = 0.003, $p = 0.010$), and marginally statistically significant negative impacts of the TTPA condition on literacy ($b = -0.007$, SE = 0.004, $p = 0.069$). There were no impacts of the TT condition on rate of change for either outcome. The first row in Figure 2 shows the predicted trajectories of students' literacy and numeracy scores over the three time points by treatment status.

Table 2. QP4G treatment status and children's school readiness skills over time ($N = 3{,}435$).

	Literacy		Numeracy		Executive function		Social–emotional	
	estimate	(SE)	estimate	(SE)	estimate	(SE)	estimate	(SE)
Fixed effects								
Intercept at T3	0.557	(0.018) ***	0.552	(0.016) ***	0.586	(0.013) ***	0.522	(0.014) ***
Time (slope)	0.124	(0.003) ***	0.115	(0.003) ***	0.069	(0.033) ***	0.085	(0.003) ***
Treatment								
TT	0.023	(0.017)	0.018	(0.015)	0.012	(0.012)	0.026	(0.013) +
TTPA	0.000	(0.016)	0.002	(0.015)	0.004	(0.012)	0.008	(0.013)
Treatment × time								
TT × time	0.004	(0.004)	−0.003	(0.003)	0.008	(0.005) +	0.005	(0.005)
TTPA × time	−0.007	(0.004) +	−0.009	(0.003) *	0.005	(0.005)	−0.005	(0.005)
Random-effects parameters								
School-level intercept (SD)	0.070	(0.005) ***	0.062	(0.005) ***	0.039	(0.005) ***	0.048	(0.005) ***
Classroom-level intercept (SD)	0.042	(0.005) ***	0.036	(0.005) ***	0.031	(0.005) ***	0.033	(0.005) ***
Child-level intercept (SD)	0.097	(0.002) ***	0.102	(0.002) ***	0.080	(0.003) ***	0.092	(0.003) ***
Child-level slope (SD)	0.042	(0.002) ***	0.036	(0.002) ***	0.051	(0.002) ***	0.029	(0.004) ***

Notes. Estimates are computed using observed scores, in four-level models: time (L1) nested in children (L2), children nested in classrooms (L3), nested in schools (L4). Effect sizes calculated accounting for the multi-level model structure (Hedges 2009).

*** $p < 0.001$. * $p < 0.05$. + $p < 0.10$.

TT = Teacher training condition; TTPA = teacher training plus parent awareness training condition.

All impact estimates computed from 100 multiply imputed data sets.

Models include the following control variables: private (vs. public) sector status of the school, six district dummies, a dummy variable for if the school was assigned to receive teacher text messages, a dummy for if the school was assigned to receive parent flyers, a series of five dummy variables accounting for within-sample mobility, child gender, age, KG level (1, 2, or 3 if KG1 and KG2 were combined in one classroom, as a categorical variable), and baseline score for each respective outcome.

3.2 Impacts on growth of non-academic skills

The second two columns in Table 2 display the estimates for EF and social emotional outcomes. The third and fourth rows display the impact estimates of QP4G at T3 (intercept), and the fifth and sixth rows display impact estimates on rate of change over time (slope), the second of which is our main parameter of interest. Similar to our previously reported impacts in year 2 (Wolf *et al.* 2019a), there were marginally statistically significant impacts of TT on SE skills at T3 (b = 0.026, SE = 0.013, p = 0.052). An examination of the impacts on rate of growth revealed that there were small, marginally significant positive impacts of the TT condition on the rate of change in children's EF skills (b = 0.008, SE = 0.005, p = 0.098). The second row in Figure 2 shows the predicted trajectories of students' EF and SE scores over the three time points by treatment status.
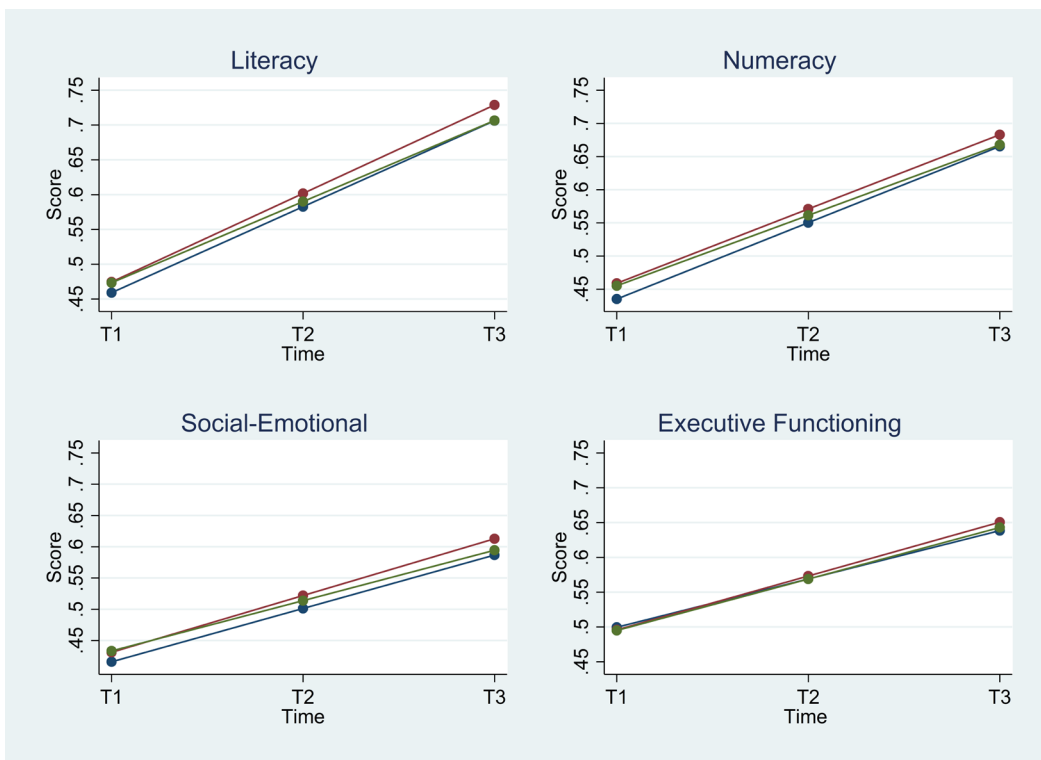

Figure 2. Trajectories of children's school readiness skills by treatment condition, by domain.

3.3 Variation by KG level

Post-estimation Wald tests (both $p < 0.001$) revealed statistically significant differences in the effects of the TT and TTPA conditions on the rate of change in children's literacy skills between students in KG1 and KG2 at programme initiation (see Appendix Table A1). Wald tests showed statistically significant differences (all $p < 0.05$) between KG1 and KG2 students at programme initiation in the effect of the treatments on children's numeracy, EF, and SE skills. However, the effect of being in the control group between KG1 and KG2 at programme initiation was marginally significant for SE skills ($p = 0.051$).

The first panel of Table 3 displays the results for children in KG1 during the intervention year, and the second panel for children who were in KG2 during the intervention year. The subgroup analyses reveal that for academic skills, there were marginally statistically significant positive impacts of the TT condition on KG1 students' literacy skills over time ($b = 0.011$, SE = 0.006, $p = 0.057$), and negative for the TTPA condition ($b = -0.003$, SE = 0.006, $p = 0.069$ for TTPA condition). The negative impacts on numeracy were restricted to children in KG2, where there were marginally statistically significant negative effects of the TTPA condition on growth in numeracy scores ($b = -0.009$, SE = 0.005, $p = 0.076$). For KG1, these effects were small ($b = -0.002$) and non-significant.

For non-academic skills, the TT condition had a positive impact on KG1 students' SE skills at T3 ($b = 0.034$, SE = 0.018, $p = 0.052$), as well as significantly steeper increases in these skills over time ($b = 0.016$, SE = 0.017, $p = 0.018$). The TTPA condition only impacted KG1 students' SE skills at T3 ($b = 0.034$, SE = 0.017, $p = 0.047$). For KG2 students, there was only a marginally significant impact of TT on SE skills at T3 ($b = 0.027$, SE = 0.016, $p = 0.078$) and no significant impacts on students' change in non-academic skills over time. There were no differences for EF across the two subgroups.

3.4 Variation by sex of the child

Wald tests revealed statistically significant differences in the effect of TT on numeracy for boys compared to girls ($p = 0.011$) and between girls and boys in the control group for SE skills ($p = 0.021$). See Appendix Table A2.

The first panel of Table 4 displays the results for boys and the second panel displays the results for girls. With regard to academic skills, there were marginally significant negative impacts of the TTPA condition on both boys' literacy ($b = -0.010$, SE = 0.005, $p = 0.067$) and girls' literacy ($b = -0.004$, SE = 0.005, $p = 0.069$). A post-estimation Wald test from the preliminary three-way interaction model revealed that there was

Table 3. QP4G treatment status and children's school readiness skills over time, by grade level.

	Literacy		Numeracy		Executive function		Social–emotional	
	estimate	(SE)	estimate	(SE)	estimate	(SE)	estimate	(SE)
Kindergarten 1 (N = 1,580)								
Fixed effects								
Intercept at T3	0.589	(0.022) ***	0.585	(0.020) ***	0.616	(0.017) ***	0.523	(0.019) ***
Time	0.137	(0.004) ***	0.129	(0.004) ***	0.082	(0.005) ***	0.086	(0.005) ***
Treatment								
TT	0.025	(0.020)	−0.001	(0.018)	0.004	(0.016)	0.034	(0.018) +
TTPA	0.015	(0.020)	0.013	(0.018)	0.010	(0.016)	0.034	(0.017) *
Treatment × time								
TT × time	0.011	(0.006) +	0.000	(0.005)	0.009	(0.007)	0.016	(0.007) *
TTPA × time	−0.003	(0.006) +	−0.002	(0.005)	0.004	(0.007)	0.007	(0.007)
Random-effects parameters								
School-level intercept (SD)	0.068	(0.026) *	0.043	(0.068)	0.049	(0.005) ***	0.599	(0.005) ***
Classroom-level intercept (SD)	0.040	(0.043)	0.055	(0.046)	0.000		0.000	
Child-level intercept (SD)	0.099	(0.003) ***	0.105	(0.003) ***	0.090	(0.005) ***	0.098	(0.004) ***
Child-level slope (SD)	0.034	(0.004) ***	0.022	(0.004) ***	0.051	(0.004) ***	0.015	(0.017)
Kindergarten 2 (N = 1,490)								
Fixed effects								
Intercept at T3)	0.697	(0.018) ***	0.688	(0.017) ***	0.664	(0.013) ***	0.617	(0.016) ***
Time (slope)	0.106	(0.004) ***	0.095	(0.003) ***	0.054	(0.005) ***	0.078	(0.005) ***
Treatment								
TT	0.017	(0.018)	0.031	(0.017) +	0.019	(0.014)	0.027	(0.015) +
TTPA	−0.013	(0.018) +	−0.013	(0.017)	0.006	(0.014)	−0.000	(0.015)
Treatment × time								
TT × time	−0.003	(0.006)	−0.002	(0.005)	0.004	(0.007)	−0.002	(0.007)
TTPA × time	−0.001	(0.006)	−0.009	(0.005) +	0.010	(0.007)	−0.007	(0.007)

Table 3. *Continued.*

Kindergarten 1 ($N = 1,580$)	Literacy			Numeracy			Executive function			Social–emotional		
	estimate	(SE)		estimate	(SE)		estimate	(SE)		estimate	(SE)	
Random-effects parameters												
School-level intercept (SD)	0.015	–		0.015	–		0.002	–		0.045	(0.005)	***
Classroom-level intercept (SD)	0.067	(0.009)	***	0.060	(0.008)	***	0.039	(0.009)	***	NA	NA	NA
Child-level intercept (SD)	0.087	(0.003)	***	0.093	(0.003)	***	0.065	(0.004)	***	0.084	(0.004)	***
Child-level slope (SD)	0.045	(0.003)	***	0.039	(0.003)	***	0.050	(0.003)	***	0.037	(0.004)	***

Notes. Estimates are computed using observed scores, in four-level models: time (L1) nested in children (L2), children nested in classrooms (L3), nested in schools (L4). Effect sizes calculated accounting for the multi-level model structure (Hedges 2009).

*** $p < 0.001$. * $p < 0.05$. + $p < 0.10$.

TT = Teacher training condition; TTPA = teacher training plus parent awareness training condition.

All impact estimates computed from 100 multiply imputed data sets.

Models include the following control variables: private (vs. public) sector status of the school, six district dummies, a dummy variable for if the school was assigned to receive teacher text messages, a dummy for if the school was assigned to receive parent flyers, a series of five dummy variables accounting for within-sample mobility, child gender, age, and baseline score for each respective outcome.

Some school-level random effects parameters were not able to be estimated, and are denoted by ' – ' in the table.

Due to model lack of convergence, the social-emotional outcome was estimated using a three-level model where multiple observations/time (L1) were nested within children (L2), who were nested within schools (L3). Therefore, there is no random-effect parameter estimate for the classroom-level ('NA').

Table 4. Exposure to QP4G and children's school readiness skills over time by sex of child.

	Literacy		Numeracy		Executive function		Social–emotional	
Boys (N = 1,754)	estimate	(SE)	estimate	(SE)	estimate	(SE)	estimate	(SE)
Fixed effects								
Intercept at T3	0.532	(0.019) ***	0.549	(0.018) ***	0.570	(0.015) ***	0.502	(0.015) ***
Time	0.125	(0.004) ***	0.115	(0.004) ***	0.067	(0.005) ***	0.081	(0.005) ***
Treatment								
TT	0.014	(0.018)	0.016	(0.017)	0.012	(0.014)	0.011	(0.015)
TTPA	−0.016	(0.018)	−0.006	(0.017)	0.001	(0.014)	0.003	(0.015)
Treatment × time								
TT × time	0.002	(0.005)	0.002	(0.005)	0.013	(0.007)	0.005	(0.006) +
TTPA × time	−0.010	(0.005) +	−0.010	(0.005) *	0.005	(0.007)	0.001	(0.006)
Random-effects parameters								
School-level intercept (SD)	0.063	(0.007) ***	0.056	(0.007) ***	0.035	(0.008) ***	0.039	(0.008) ***
Classroom-level intercept (SD)	0.057	(0.007) ***	0.048	(0.007) ***	0.039	(0.008) ***	0.042	(0.008) ***
Child-level intercept (SD)	0.097	(0.003) ***	0.103	(0.003) ***	0.084	(0.004) ***	0.093	(0.004) ***
Child-level slope (SD)	0.043	(0.003) ***	0.035	(0.003) ***	0.050	(0.003) ***	0.033	(0.005) ***
Girls (N = 1,681)								
Fixed effects								
Intercept at T3	0.567	(0.020) ***	0.562	(0.018) ***	0.602	(0.014) ***	0.528	(0.016) ***
Time (slope)	0.122	(0.004) ***	0.115	(0.004) ***	0.072	(0.005) ***	0.090	(0.005) ***
Treatment								
TT	0.025	(0.019)	0.013	(0.017)	0.011	(0.014)	0.039	(0.016) *
TTPA	0.013	(0.019)	0.002	(0.017)	0.009	(0.014)	0.015	(0.016)
Treatment × time								
TT × time	0.006	(0.005)	−0.009	(0.005) +	0.003	(0.007)	0.006	(0.006)
TTPA × time	−0.004	(0.005) +	−0.008	(0.005)	0.004	(0.007)	−0.011	(0.006) +

Table 4. *Continued.*

	Literacy		Numeracy		Executive function		Social–emotional	
Boys (N = 1,754)	estimate	(SE)	estimate	(SE)	estimate	(SE)	estimate	(SE)
Random-effects parameters								
School-level intercept (SD)	0.076	(0.006) ***	0.064	(0.006) ***	0.031	(0.010) ***	0.044	(0.007) ***
Classroom-level intercept (SD)	0.031	(0.009) ***	0.030	(0.010) ***	0.038	(0.008) ***	0.039	(0.009) ***
Child-level intercept (SD)	0.091	(0.003) ***	0.097	(0.003) ***	0.073	(0.004) ***	0.089	(0.004) ***
Child-level slope (SD)	0.042	(0.003) ***	0.037	(0.003) ***	0.052	(0.003) ***	0.068	(0.006) ***

Notes. Estimates are computed using observed scores, in four-level models: time (L1) nested in children (L2), children nested in classrooms (L3), nested in schools (L4). Effect sizes calculated accounting for the multi-level model structure (Hedges 2009).

*** $p < 0.001$. * $p < 0.05$. + $p < 0.10$.

TT = Teacher training condition; TTPA = teacher training plus parent awareness training condition.

All impact estimates computed from 100 multiply imputed data sets.

Models include the following control variables: private (vs. public) sector status of the school, six district dummies, a dummy variable for if the school was assigned to receive teacher text messages, a dummy for if the school was assigned to receive parent flyers, a series of five dummy variables accounting for within-sample mobility, age, KG level (1, 2, or 3 if KG1 and KG2 were combined in one classroom, as a categorical variable), and baseline score for each respective outcome.

not a significant difference between the effect of TTPA on literacy skills for boys and girls (p = 0.537). Furthermore, there was a significant negative impact of the TTPA condition on the rate of change in boys' early numeracy skills (b = −0.010, SE = 0.005, p = 0.037), while the TT condition had a marginally significant negative impact girls' numeracy skills (b = −0.009, SE = 0.005, p = 0.078).

For the non-academic skills, there was a marginally significant, positive impact of the TT condition on the rate of change in boys' EF skills over time (b = 0.013, SE = 0.007, p = 0.054), but not for girls (b = 0.003, p = n.s.). Finally, the TT condition had a significant, positive impact on girls' social emotional development at T3 (b = 0.039, SE = 0.016, p = 0.013), but a marginally significant negative impact on rate of growth for girls' SE skills (b = −0.011, SE = 0.006, p = 0.082).

4. DISCUSSION

This article has presented two-year longitudinal experimental impacts on children's school readiness skills of a teacher training and coaching programme, implemented with and without parental-awareness meetings, in pre-primary schools in Ghana. Consistent with the QP4G programme theory of change and a holistic perspective on early childhood education and development, we focused on outcomes in multiple domains, addressing key academic and non-academic skills necessary for school readiness (for example, Blair & Razza 2007). In addition, we analysed the data in a manner consistent with the randomised, experimental design of the evaluation and with the developmental nature of the longitudinal data, estimating school-level intervention effects on children's developmental growth parameters across three repeated time points.

The article was designed to address a number of limitations in current research on exposure to early childhood education in LMICs. To our knowledge, it is the first evaluation of ECE impacts on trajectories of learning in SSA. The results reveal a complementary but new set of findings to two previous papers published on the study examining impacts at one point-in-time (Wolf *et al.* 2019a, 2019b).

4.1 Impacts of teacher training and coaching on rate of school readiness skills growth

The teacher training implemented by itself did not have an impact on the rate of growth of children's academic skills or SE skills. There were marginally significant positive impacts on growth in EF from TT (p < 0.10). This is contrast to previous analyses examining impacts at the end of implementation year (Wolf *et al.* 2019a) and

one year later (Wolf *et al.* 2019b), which showed improvements in literacy, numeracy, and SE skills during the implementation year, and sustained impacts on SE skills one year later.

The results suggest that, while the QP4G teacher training improved academic outcomes (both literacy and numeracy) during the intervention year (Wolf *et al.* 2019a), these changes were not sufficiently large to ultimately change children's academic trajectories over the two years, suggesting that children did not sustain or build on the previous gains in the following school year 2. As most children in the sample had a new teacher in the second year, these are important findings that suggest aligning children's subsequent schooling with quality improvements in ECE may be necessary to sustain gains on academic skills. Research from the United States has found that in the school year following preschool, children's subsequent classrooms often repeat the same academic content that children learned in the previous year. As a result, children who did not attend preschool 'catch up', and any gains on academic skills from the previous year converge (Weiland 2018). If that is the case in this context, the results suggest that training teachers to track individual children and build on their existing skills to support individualised learning may be key to sustaining gains on academic outcomes from improved ECE quality. Finally, the new results provide suggestive evidence that improving activity-based instruction and positive behaviour management in ECE can improve children's trajectories of EF skills. EF and self-regulatory behaviours are increasingly seen as central for children's successful adaptation to school, as such skills have been linked to children's growth in academic achievement (for example, Bull & Lee 2014, Jacob & Parkinson 2015) and even pro-social skills (Wolf & McCoy 2019). EF is susceptible to both the negative impact of early adversity and positive inputs, because the brain regions that support these skills have a prolonged developmental trajectory (Shonkoff & Phillips 2000, Zelazo & Carlson 2012). Understanding whether the changes from QP4G in children's EF trajectories lead to longer term impacts on children's schooling outcomes is an area of future research that we hope to pursue.

4.2 Counteracting impacts of parental-awareness meetings

Contrary to our prediction, when the same programme was implemented alongside three parental-awareness meetings, administered through school PTAs by local government district coordinators and designed to increase communication between parents and teachers, we found impacts on *reduced* rate of growth on children's school readiness skills. These negative impacts were restricted to academic outcomes, including marginally significant negative effects on growth in literacy ($p < 0.07$), and statistically significance negative effects on growth in numeracy skills. While

counter-intuitive, these findings are consistent with previous articles that showed the parental-awareness intervention had counteracting impacts on children's school readiness outcomes.

Analysing these findings requires a deeper discussion of the context in which the programme was implemented. Previous studies have shown that Ghanaian parents value early education and demand academically focused, rigorous instruction from teachers (Bidwell *et al*. 2014, Kabay *et al.* 2017). Interestingly, parents' school involvement has been shown to negatively predict Ghanaian children's school readiness skills (Wolf & McCoy 2017), suggesting that parents may have a vision for schooling that is in contradiction to developmental learning processes. Thus, the QP4G approach to engaging parents in KG education through parental-awareness meetings without changing their preferences and practices may have conflicted with the teacher training in counterproductive ways. Furthermore, the study took place in peri-urban and semi-rural communities in the fastest growing and most diverse region in the country. Research in human development indicates that urbanisation is a powerful force in shaping changing expectations for children's learning (Greenfield 2009), and research with parents in this region of Ghana suggests that parents view preschool as a way to prepare children for academic learning and socialisation (Kabay *et al.* 2017). The messages relayed in the QP4G programme may have been interpreted by parents as threatening their goals for their children's academic preparation and socialisation. It is possible that parents disagreed with the messages from the training and favoured traditional, teacher-directed, academically rigorous approaches (for example, Bidwell *et al.* 2014).

Finally, a follow-up qualitative study with parents and teachers from this treatment condition revealed three important insights: parents pushed back on the messages related to positive disciplinary practices; teachers communicated with parents primarily about concerns related to children; and teachers felt frustrated in trying to communicate with parents Wolf 2019). These findings suggest that the intervention may have successfully increased parent–teacher communication—as it was designed to—but this in fact led to disagreement and frustration among both parents and teachers in ways that was ultimately harmful to children. These findings suggest a misalignment between parents' and teachers' expectations for ECE. This is consistent with a recent study in Tanzania, which found that parents consider respect and social compliance as core values that they hope schooling will instil in their children, while teachers value children's confidence and curiosity (Jukes *et al.* 2018). More research is needed to find effective ways to engage parents in their child's education in a positive way, which may be critical for sustainably changing teacher practice and children's development.

4.3 Differences by child grade and sex

Subgroup analyses by grade level at programme initiation (KG1 vs. KG2) and child sex (boys versus girls) showed that there were larger gains for KG1 children at programme initiation in the TT condition for literacy and SE skills, and larger negative effects for boys in the TTPA condition for numeracy skills. The stronger gains for KG1 children at programme initiation suggest that exposure to activity-based, developmentally appropriate instructional practices in the first year of pre-primary school can improve children's early schooling trajectories in obtaining both academic and non-academic domains. The results also suggest that, in this case, earlier intervention (4-year-olds versus 5-year-olds) is more effective in improving children's transition to school.

The larger negative effects for boys in the TTPA condition, particularly on numeracy and literacy skills, suggest that the counteracting effects of the parental-awareness meetings were restricted to academic skills. Girls in Ghana have historically experienced lower educational outcomes than boys (UNESCO 2014). Interestingly, there is gender parity in pre-primary school enrolment in Ghana, and gender parity in school enrolment declines with school progression (UNGEI 2012). Thus, it is possible that, while parents enrol boys and girls in pre-primary school at equal rates, inequities in investments in their children's education occur in other ways, with parents emphasising schooling as the basis for their children's future (Kabay *et al.* 2017) more for boys than girls.

4.4 Limitations and conclusions

This study has numerous strengths: a randomised experimental design with sufficient power to detect small effects, the use of culturally adapted measures collected by Ghanaian data collectors, longitudinal tracking of children for a year after the end of the one school-year intervention, and assessment of multiple sub-domains of children's school readiness. But there also are important limitations. First, there was significant attrition of the children in the sample (about one fifth of the baseline sample), and significant missing responses for about one third of the caregivers due to a difficulty obtaining correct phone numbers. The use of multiple imputation and multiple controls probably limits any bias due to attrition. Second, we assess trajectories over three waves, limiting our ability to examine non-linear trajectories and to examine growth over a longer time period. We modeled linear growth because this was the most reliable approach with three time points of data, as opposed to spline or quadratic patterns of growth that require at least four time points of data for reliable estimation (Singer & Willett 2003). Therefore, our data did not allow us to assess potential non-linear

change in outcomes. Third, due to time and resource constraints, we collected very little data on the implementation of the parental-awareness training and parents' engagement in and perceptions of this training. We are thus unable to understand mechanisms of change related to this treatment condition, an important limitation given the negative impacts of this treatment on children's academic skill growth.

Despite these limitations, this report of two-year impacts of an integrated ECE quality improvement intervention, focused on transforming classrooms from rote memorisation of academic concepts and a strict disciplinarian approach to one that incorporates activities, emotional support, and positive behaviour management, provides important contributions to the field of international education and global ECE. This study provides good evidence that such universal quality improvement school-based interventions, delivered to whole populations of children, can result in positive changes in children's development. At the same time, the results of the parental-awareness intervention caution the field not to assume engaging parents will always be positive, and push future interventions to take context, culture, and parental desires for their children's education and socialisation into account.

Several questions remain and there are several future directions for policy-relevant research to explore, including: What are the mechanisms of parents' roles in child development for pre-schoolers? How can parents' interests and activities be harnessed to be more complementary with improved teacher training? Are there persistent impacts on children over longer time horizons, including what some have termed 'sleeper effects' for some of the non-academic outcomes? To what extent do altered academic trajectories in these two years affect children's outcomes in primary schools. And to what extent or with what modifications are the effective aspects of teacher training in peri-urban Ghana transferable to other contexts? In our ongoing research we are attempting to answer some of these questions. With such ongoing research we hope to contribute further to knowledge about what makes ECE most effective in contexts such as in Ghana.

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APPENDIX

Table A1. Results from Wald tests comparing KG levels.

	KG Level						
	Literacy		**Numeracy**		**Executive function**		**Social–emotional**
KG1vs KG2 for treatment	*F*-statistic		*F*-statistic		*F*-statistic		*F*-statistic
KG1-TT vs KG2-TT	77.870	***	72.540	***	30.060	***	72.540 ***
KG1-TTPA vs KG2-TTPA	31.680	***	72.050	***	9.890	***	72.050 ***
KG1-control vs KG2-control	37.890	***	49.490	***	20.050	***	49.490 ***
KG1: comparing treatment							
KG1-TT vs KG1-TTPA	8.050	***	1.110		1.200		1.110
KG1-TT vs KG1-control	3.200	+	0.040		1.720		0.040
KG1-TTPA vs KG1-control	0.790		0.630		0.080		0.630
KG2: comparing treatment							
KG2-TT vs KG2-TTPA	0.250		0.840		1.530		0.840
KG2-TT vs KG2-control	0.100		0.420		0.390		0.420
KG2-TTPA vs KG2-control	0.020		2.340		3.300	+	2.340

Notes. Estimates are computed using observed scores, in four-level models: time (L1) nested in children (L2), children nested in classrooms (L3), nested in schools (L4). Effect sizes calculated accounting for the multi-level model structure (Hedges 2009).

*** $p < 0.001$. * $p < 0.05$. + $p < 0.10$.

KG1 ($N = 1,580$) KG2 ($N = 1,490$)

Models include the following control variables: private (vs. public) sector status of the school, six district dummies, a dummy variable for if the school was assigned to receive teacher text messages, a dummy for if the school was assigned to receive parent flyers, a series of five dummy variables accounting for within-sample mobility, child gender, age, KG level (1, 2, or 3 if KG1 and KG2 were combined in one classroom, as a categorical variable), and baseline score for each respective outcome.

Table A2. Results from Wald tests comparing boys and girls.

	Sex of child						
	Literacy		Numeracy		Executive function		Social–emotional
Girls vs Boys for treatment	*F*-statistic		*F*-statistic		*F*-statistic		*F*-statistic
Girls-TT vs Boys-TT	77.870	***	72.540	***	30.060	***	72.540	***
Girls-TTPA vs Boys-TTPA	31.680	***	72.050	***	9.890	***	72.050	***
Girls-control vs Boys-control	37.890	***	49.490	***	20.050	***	49.490	***
Girls: comparing treatment							
Girls-TT vs girls -TTPA	8.050	***	1.110		1.200		1.110	
Girls-TT vs Girls-control	3.200	+	0.040		1.720		0.040	
Girls-TTPA vs Girls-control	0.790		0.630		0.080		0.630	
Boys: comparing treatment							
Boys-TT vs Boys-TTPA	0.250		0.840		1.530		0.840	
Boys-TT vs Boys-control	0.100		0.420		0.390		0.420	
Boys-TTPA vs Boys-control	0.020		2.340		3.300	+	2.340	

Notes. Estimates are computed using observed scores, in four-level models: time (L1) nested in children (L2), children nested in classrooms (L3), nested in schools (L4). Effect sizes calculated accounting for the multi-level model structure (Hedges 2009).

*** $p < 0.001$. * $p < 0.05$. + $p < 0.10$.

Boys ($N = 1,754$) Girls ($N = 1,681$)

Models include the following control variables: private (vs public) sector status of the school, six district dummies, a dummy variable for if the school was assigned to receive teacher text messages, a dummy for if the school was assigned to receive parent flyers, a series of five dummy variables accounting for within-sample mobility, child gender, age, KG level (1, 2, or 3 if KG1 and KG2 were combined in one classroom, as a categorical variable), and baseline score for each respective outcome.