***Title page with author details**

Running head: ECE AND CHILD DEVELOPMENT

Early Childhood Education and Child Development in four countries in East Asia and the Pacific

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Abstract

This study examined associations between participation, intensity (hours per week), duration (months attended), and total dosage (total hours attended) in early childhood education (ECE) and children's cognitive, language, and socio-emotional development in Cambodia, China, Mongolia, and Vanuatu using data from the validation sample of the East Asia-Pacific Early Child Development Scales (EAP-ECDS). The total sample analyzed included 4,712 ethnic majority children (2,336 girls), ranging in age from 36 to 71 months. Controlling for age, gender, parental education and occupation, household wealth, and urbanicity: (i) children who received ECE had significantly better cognitive, language, and socio-emotional development than those who did not; (ii) among children who did not attend ECE, age-adjusted scores were significantly lower for older children than they were for younger children; (iii) increased ECE intensity was associated with higher scores in all developmental domains in Mongolia, higher language scores in Cambodia, and lower socio-emotional scores in Cambodia and China; and (iv) ECE dosage was positively associated with cognitive and socio-emotional scores in China, and language scores in Mongolia. Overall, results indicate that ECE is beneficial for children's early development, though many children in the region are not able to reap these rewards due to barriers to access. Results suggest efforts to ensure all children have access to quality ECE be exerted so that these benefits can be realized.

Keywords: early childhood education; early childhood development;

East Asia-Pacific Early Child Development Scales (EAP-ECDS)

Early Childhood Education and Child Development in four countries in East Asia and the Pacific

Proximal and distal environments, which vary widely across contexts and countries, have a marked influence on child development (Bronfenbrenner & Morris, 2006). Encouragingly, a growing body of evidence has demonstrated a positive relation between participation in Early Childhood Education (ECE), a proximal environment, and the development of cognitive and non-cognitive skills in both high income and low and middle income countries (LMIC) (Claessens & Garrett, 2014; Engle et al., 2011; Larson, Russ, Nelson, Olson, & Halfon, 2015; Rao, Sun, Chen, & Ip, 2017; Sylva et al., 2006; Weiland & Yoshikawa, 2013). However, systematic evaluation of the relation between ECE and child development has typically only been conducted in high income societies, although only 18% of children are born in high income countries; the remaining 82% live in LMIC (UNESCO, 2015).

Children in LMIC are likely to suffer from adversities that are associated with poor development and learning (Black et al., 2017). Interventions such as ECE have been shown to be effective in improving child development outcomes (Britto et al., 2017). Therefore, it is important for developmental science to elucidate developmental and environment factors that are associated with positive child development, identify promising targets for interventions and shed light on the processes that account for positive impacts (Wuermli, Tubbs, Petersen, & Aber, 2015), particularly so in LMIC considering the paucity of evidence to date.

Against this background, this paper takes advantage of data from the validation sample of the East Asia-Pacific Early Child Development Scales (EAP-ECDS), the first developmental assessment measure created on the basis of the culture and values of a world region, to examine the influence of ECE – specifically participation and quantity – on child development across key developmental domains in four LMIC across the East Asia Pacific (EAP) region. In doing so, we

seek to gain an in-depth understanding of the relation between ECE and children's early learning and development in the region, with the overarching goal of equipping governments with the evidence required for appropriate policy-making, helping to ensure all children are afforded the best start in life.

ECE Participation and Quantity and Child Development Outcomes

ECE interventions, including center-based programs, in LMIC are typically designed to enhance cognition and children's school readiness. A recently conducted systematic review and meta-analysis of the impact of early childhood interventions on the development of children from birth to 8 years in LMIC considered the effect of different interventions on multiple child outcomes: cognition, motor development, psychosocial functioning, and growth (Rao, Yousafzai & Ip, 2017). The authors reported overall weighted average coefficient size for cognition outcomes (0.49), motor performance (0.17) and psychosocial functioning (0.13); with smaller coefficient magnitudes for psychosocial functioning and motor performance suggesting that ECE interventions in LMIC may not have a strong influence on these two domains.

In addition to participation/non-participation, it is necessary to examine the association of the quantity of ECE – that is, the amount of children's exposure to ECE – with child development, but this parameter has been rarely examined in LMIC. Evidence regarding the relation between the amount and type of ECE experience and child development is important to inform policymakers on the most effective investments that can be made to support child development. Against this background, the current study works to fill this knowledge gap by examining the relation between the quantity of center-based ECE and early child development in four LMIC in East Asia and the Pacific. Specifically, it considers whether ECE program participation, intensity, duration, and total dosage are related to children's cognitive, language

and socio-emotional development, controlling for child and family characteristics. An examination of the relation between ECE quantity and child developmental outcomes may help shed light on the amount of ECE provision that is necessary to be associated with positive changes in children's development.

ECE intensity and child development

The intensity of an ECE program tallies the exposure of participants and may include session duration and frequency (Wasik & Snell, 2015). Supplementary Table 1 summarizes the findings of some studies on ECE intensity and duration. Research in developed countries indicates that program intensity has had both positive and negative associations with child outcomes. For instance, studies in the U.S. suggest that more hours of center-based care are associated with greater academic benefits and increased negative behavioral consequences (e.g., Gibbs, 2014; Loeb et al., 2007; Votruba-Drzal, Li-Grining, & Maldonado-Carreño, 2008; Walters, 2014). The relation between program intensity and child development also varies across different ethnic and socioeconomic status (SES) groups. Gibbs (2014) found that children who had attended full-day kindergarten had better literacy skills than those who had attended half-days; and further, Hispanic students and children who had started the year with low literacy levels were reported to experience the largest gains. Based on The Longitudinal Study of Australian Children (LSAC) data, Yamauchi and Leigh (2011) found that negative associations between full-time center-based care and children's behavioral outcomes were the largest among children from high SES families. Importantly, this suggests that increased intensity in ECE could be most beneficial for disadvantaged children, and there is a need for similar research to be conducted in LMIC in order to determine if the findings of ECE intensity are consistent with those in high income countries.

ECE duration and child development

The present study also investigates the relation between ECE duration and child development. Duration denotes the length of time in a program (e.g., six months, three years). In general, research has demonstrated that increased ECE duration results in better school readiness, although these associations may fade out (Wasik & Snell, 2015). For instance, Domitrovich et al. (2013) explored the relation between preschool duration and school readiness among children from low income families in the U.S. and found that two years of preschool led to increased literacy and numeracy skills compared to only one year of preschool. Research in Germany has also examined the influence of preschool duration on school readiness, reporting that it is ideal that children attend preschool for at least two years, and that immigrant children in particular benefit from preschool attendance longer than two years in duration (Biedinger, Becker, & Rohling, 2008). Data from the Effective Provision of Preschool Education (EPPE) project in the UK has also demonstrated a positive link between preschool duration and children's cognitive development (Sammons et al., 2004). In Australia, data from the LSAC has demonstrated that greater preschool duration as well as greater intensity from infancy and throughout preschool is linked with increased fluid intelligence and has small negative associations with children's behavioral outcomes (Coley, Lombardi, & Sims, 2015). More recently, Burchinal and colleagues (2016) found that children who attended two years of the Head Start ECE program had better vocabulary and literacy skills than those who attended one year only, both immediately after attending the program and again at the end of kindergarten. In contrast, the same study found that this was not necessarily true for an additional year of high quality care amongst children with two years of center-based ECE experience (Burchinal et al, 2016).

The long-term impacts of ECE duration have also been investigated. A long-term follow-up of participants in the Chicago Longitudinal Study reported that children who attended a high quality preschool program for two years were less likely to receive special education, commit crime, or be abused or neglected than those who attended the program for one year only, though no differences were found in children's cognitive or academic outcomes (Arteaga, Humpage, Reynolds, & Temple, 2014). Evidently, duration is an important aspect of effective ECE. Thus, research on duration is also required in LMIC, in order to determine optimal ECE program characteristics and maximize the benefits of ECE in these countries.

As there are difficulties associated with randomly assigning children to receive different amounts of ECE, a series of studies conducted in the U.S. used propensity score matching to identify both the short- and long- term effects of one-year versus two-years of ECE attendance on child outcomes. These studies examined children's early language and literacy skills (Frede, Jung, Barnett, & Figueras, 2009; Skibbe, Connor, Morrison, & Jewkes, 2011; Wen, Leow, Hahs-Vaughn, Korfmacher, & Marcus, 2012), numeracy skills (Frede, Jung, Barnett, & Figueras, 2009; Wen, Leow, Hahs-Vaughn, Korfmacher, & Marcus, 2012) and schooling outcomes, including grade retention and special education placement (Arteaga, Humpage, Reynolds, & Temple, 2014). Taken together the results from these studies suggest a positive relation between increased ECE duration and children's developmental outcomes.

There is some evidence from developing countries indicating that the duration of ECE experienced is related to child development. For example, Behrman (2006) reported that children in the Philippines who had been exposed to ECE programs for more than 17 months showed higher IQ scores than those who had not. In Bolivia, children who had attended ECE programs for at least seven months showed significant gains in their development, and greater attendance

duration was associated with larger gains in children's outcomes. Finally, Nores and Barnett (2010) examined the benefits of 30 early childhood interventions in 23 non-U.S. countries. Their meta-analysis revealed that interventions that lasted longer than one year produced more benefits than those lasting less than a year. Further studies are needed to better illustrate how ECE duration supports early child development in different domains in the developing world.

ECE total dosage and child development

In an ECE setting, dosage may include session duration (i.e., hours of attendance in a given period of time), session frequency (i.e., number of days of attendance), and program duration (i.e., the period of exposure in the program). As Wasik and Snell (2015) explain, cumulative dosage can be calculated using these variables. To date however, few studies have investigated the association of the cumulative dosage of ECE with child development (Wasik & Snell, 2015). The research that is available on ECE dosage generally indicates that increased dosage is linked to positive outcomes for children. For example, Patel et al. (2016) found that total number of hours in integrated early childhood services significantly predicted children's physical health and well-being, language and cognitive development, and communication and general knowledge. In contrast, greater dosage may also have negative associations with behavioral functioning (Coley et al., 2015).

In addition, studies on ECE quantity suggest complexity in its relation with child development. For example, findings from the EPPE Project in the U.K. showed that although the number of individual sessions attended and the duration of program experience predicted children's cognitive development at school entry, half-time vs. full-time enrollment (intensity) was not predictive of children's outcomes (Sylva et al., 2004). As the composite of both ECE intensity and duration, the relation between cumulative ECE dosage and child development

therefore may not always be linear and both ceiling and threshold effects might exist (Nicholson, Lucas, Berthelsen, & Wake, 2010). Therefore the present study aims to explore the relation between ECE total dosage and child development in a more systematic and nuanced way to better capture the complexity in the relation between ECE dosage and early child development.

Age, ECE and child outcomes

Although research has generally shown that more time in high-quality ECE programs is associated with positive developmental outcomes (Yazejian, Bryant, Freel, & Burchinal, 2015), the most appropriate or optimal age of entry into early childhood education and care programs has been a source of debate. Evidence from the U.S. suggests that, although childcare can benefit language development, exposure to long hours of childcare in infancy (Bradley & Vandell, 2007) and early entry into early education and care (Yazejian et al., 2015) are associated with behavioral problems. Evidence from Norway has also demonstrated benefits to language development of participation in childcare (Lekhal, 2012) but, in contrast to the evidence from the U.S., suggests that age of entry effects on child aggression were negligible by age four (Dearing, Zachrisson, & Nærde, 2015). Older age of entry into kindergarten has been shown to be associated with higher mathematics and science test scores across several different OECD countries (Bedard & Bhuey, 2006), but early-age achievement gaps may narrow over time (Huang & Invernizzi, 2012). It is also important, therefore, to consider whether age moderates any relation between participation in ECE programs and developmental outcomes.

ECE in East Asia and the Pacific

Despite the benefits of ECE, only 74% of children in the EAP region received pre-primary education in 2012 (UNESCO, 2016). There are differences in ECE participation based on family wealth/SES with children from more economically advantaged backgrounds more

likely to attend ECE than other children. In Mongolia, for instance, being poor or marginalized reduces the chances of a child attending early learning programs (UNESCO, 2015). As a result, many children in the region are likely to drop out of school or repeat grades due to a lack of readiness for formal schooling. There are also wide disparities in human development indicators within and across the EAP region. For example, the under-five mortality rate in 2015 was 10.7 in China but was 28.7 in Cambodia (United Nations, 2016). Evidently, continued efforts to promote children's development and reduce disparities across the EAP through the provision of ECE are required; as is the investigation of the influence of ECE on children's outcomes in order to help guide early childhood policy and programs in the region.

Supplementary Table 2 demonstrates large contextual variations between the countries included in this study (data are from 2013-14, close to when the study was conducted). For example, population size varied from 270,000 in Vanuatu to 1.38 billion in China. The gross domestic product (GDP) per capita income in 2014 ranged from US$1,095 in Cambodia to US$7,590 in China. Among the four countries, the highest percentage of children under the age of five suffering from moderate or severe stunting was in Cambodia (32%), and the lowest was in China (9%). Gross enrollment ratio in pre-primary education ranged from 18% in Cambodia to 86% in Mongolia in 2014 (UNESCO, 2016). The four countries discussed in this paper reflect the variability in the EAP region and were among the countries included in the EAP-ECDS validation sample. It should be noted that ECE is not compulsory in any of the four countries studied, though all children in our sample from China were enrolled in ECE, as on this occasion, it was not possible to collect data from children not enrolled. In all countries we examined the association between participation (including participation intensity, duration, and dosage) in center-based ECE and child outcomes. We chose to examine center-based ECE as this is the

most common form of ECE in the countries studied. Our definition of center-based ECE included kindergartens, pre-primary classes, or community preschools and did not include parent-child playgroups or drop-in centers. Below we provide a brief summary of the ECE landscape in each of the four countries included in the current study.

Cambodia. In Cambodia, ECE funding is perceived to be the responsibility of each locality and almost all communes and districts have one or two preschools providing educational services to children aged three to five. There are significant disparities in the availability of services across urban and rural areas of the country; whilst urban areas comprise only 15% of the preschool population, they account for about 25% of total preschool enrollment (UNESCO International Bureau of Education, 2011).

China. In China, there are three main types of ECE centers: nurseries, kindergartens and pre-primary classes. There is, however, a vast gap between rural and urban areas, and between the eastern and western provinces in the provision of ECE services. The enrollment ratio in urban areas has been as high as 99%, while in some poor and rural areas, such as Gansu, the gross enrolment ratio is as low as 52.3% (Ministry of Education of China, 2015). It was estimated that around 32 million three- to six- year-olds living in rural areas of the country did not have access to ECE (Rao, Sun, Zhou, & Zhang, 2012), and most of children who have access to ECE usually attend only one year of ECE compared to the three years of ECE that children living in urban areas typically receive (Wu, Young, & Cai, 2011).

Mongolia. Kindergartens that are publicly subsidized comprise approximately 90% of ECE centers in Mongolia (UNESCO International Bureau of Education, 2011). About 70% of entrants to Primary 1 in 2012 had some form of ECE experience. Despite relatively high participation, the coverage of early childhood services across the country is unequal, with the

highest rates found in major cities and the lowest in the western provinces. Additional ECE services such as mobile kindergartens, short-term preschool summer courses and home training are available in some areas, but the quality of such programs is often poor and the duration is short.

Vanuatu. Only recently has preschool education become a focus of the Vanuatu government. Funding for ECE is lacking due to inadequate allocation of resources to the early childhood sector, and recently, the coverage of preschool education has been dropping. This is due to a decrease in the number of ECE centers as well as the number of children attending preschool. As a result, the gross enrollment ratio declined from 119 in 2006 to 93 in 2010 but was 97 in 2013 (UNESCO, 2016; UNESCO Institute of Statistics, 2016).

The Current Study

The present study focuses on exploring associations between ECE participation and quantity (intensity, duration, and total dosage) and child development in four countries across the East Asia and Pacific region. It examines whether ECE (i) program participation; (ii) intensity; (iii) duration; and (iv) total dosage are related to children's cognitive, language and socio-emotional development. Further it considers whether children's age moderates the relation between ECE program experience and cognitive, language and socio-emotional development.

Method

Participants

The data for this study come from the EAP-ECDS validation sample, collected in 2013-2014 in six countries. Data from four of these countries (Cambodia, China, Mongolia, and Vanuatu) are included in the analysis. Data from Papua New Guinea and Timor-Leste were excluded due to low ECE participation rates of 2.9% and 6.4%, respectively (children in Papua

New Guinea typically start attending ECE at the age of six). With the exception of China, the sampling plan for the validation study was determined in conjunction with the National Census Department or National Statistics Institute, and used multi-stage sampling to produce a nationally representative sample (Authors, 2014, 2017, 2018). In China, five provinces with widely varying levels of economic development were sampled: Gui Zhou, Hei Long Jiang, Jiang Su, Shanghai and Zhejiang. A total of 41 kindergartens were sampled from within these provinces; 18 from rural and 23 from urban areas. Among these, eight were private and 33 were public kindergartens. Children were sampled from within each kindergarten. In all countries, the sample was stratified by age, gender, and urban/rural residence. Children with special educational needs (identified or suspected) were not assessed. Data were collected on seven different domains of development. The final analytic sample for this study includes 4,712 ethnic majority children (2,336 girls), ranging in age from 36 to 71 months, with non-missing data in at least five of the seven developmental domains, as well as non-missing urbanicity and ECE participation information (see Table 1). Sampling of ethnic minority children was insufficient to be included in these analyses. Details of the sample disaggregated by province can be found in Supplementary Table 3.

Measures

The East Asia Pacific Early Child Development Scales (EAP-ECDS)

Based on the Early Learning and Development Standards of countries in the region, the EAP-ECDS were developed to assess the holistic development of children ranging in age from three to five years across East Asia and the Pacific. The Scales include 85 directly assessed items categorized into seven domains: Cognitive Development (21 items, Cronbach's alpha ranged from .88 to .94 across six countries); Language and Emergent Literacy (16 items, α = .89 to .95);

Socio-emotional Development (15 items, α = .89 to .94); Cultural Knowledge and Participation (10 items, α = .89 to .94); Motor Development (7 items, α = .70 to .77); Health, Hygiene, and Safety (9 items, α = .84 to .94); and Approaches to Learning (7 items, α = .88 to .92) (Authors, 2014). Each item has a binary response scale with a score of 1 indicating successful completion and 0 indicating unsuccessful completion. The EAP-ECDS are untimed; total administration time is normally 45-60 minutes, though this is dependent upon a child's age, ability, temperament, mood, as well as rapport with the assessor. Items are administered in a fixed order in the local language. Inter-rater reliability between each assessor and a supervisor is at least 85% prior to formal testing, and inter-rater reliability between assessors and supervisors is re-evaluated approximately every 20 test administrations (Authors, 2018). The EAP-ECDS has been demonstrated to be a psychometrically robust and culturally appropriate measurement tool for the region. For example, item analysis demonstrated that test items differentiate between the ability of participants, and that there was no systematic bias between countries; content validity was assessed by soliciting the advice of experts in the region and modifying items as appropriate; exploratory factor analyses showed one main factor in each country; and confirmatory factor analysis showed a one factor model had adequate (RMSEA test) or good fit (CFI, TLI, and SRMR tests) across the sample as a whole (Authors, 2014, 2018).

We focus on the associations between ECE participation and Cognitive Development (counting, addition/subtraction, short-term memory, concepts, behavioral inhibition, and knowledge of shapes), Language and Emergent Literacy (expressive language, grapheme knowledge, and writing/drawing), and Socio-emotional Development (etiquette, social comprehension, emotional recognition, and perspective-taking). Authors (2014) provide full information regarding items that are included in each domain. Examples of items are provided in

Supplementary Table 4.

In order to minimize first-order age effects on children's exposure to ECE, country- and age- adjusted z-scores were calculated from 1-month age-specific means and standard deviations of the EAP-ECDS domain score in each age category. Sample populations in each country were used as their own reference for the z-scores due to the lack of regional age-adjusted standards. For ease of interpretation of the results, z-scores were converted to a non-zero point scale centered at 100 with a standard deviation of 15 points.

ECE participation, intensity and duration

Information on children's ECE participation was collected from parents during an individual interview in Mongolia, Vanuatu and Cambodia. In China, given high parental literacy rates, questionnaires were completed in small groups and a research assistant was present to assist. Estimates for the overall association of ECE participation with children's EAP-ECDS performance are based on parent's yes/no response to the question: "Has your child ever attended any organized learning or early childhood education program, such as a private or government facility, including kindergarten or community childcare or drop-in center?" As all children who attended center-based ECE were assessed in their centers or a nearby primary school, we are confident that all children in the study attended center-based ECE. Further, none of the children in the study were in formal primary school. Children were either attending center-based ECE or not attending; therefore a binary variable was created to represent ECE participation. We did not carry out an intervention but simply examined the association of ECE experience and children's cognitive, language, and socio-emotional development.

Subset analyses to explore the association of performance on the Scales with participation intensity (number of hours per week the child attended) and duration (number of months the

child has been in the program) were restricted to children who had ever attended a program. Intensity response options were grouped into five categories: less than 10 h, 11 to 20 h, 21 to 30 h, 31 to 40 h, and more than 40 h. Duration response options were grouped into eight categories from less than 3 m to more than 37 m. The earliest age at which a child could have started an organized learning or ECE program was assumed to be 30 m. Parent-reported durations that were longer than expected for the child's age were replaced with the maximum for age (~13% of sample). Summary statistics for participation, intensity and duration of participation by response option and country are shown in Table 2.

ECE total dosage

Following Wasik and Snell (2015), the variable ECE total dosage was created from the variables ECE intensity and ECE duration. Specifically, ECE total dosage = ECE intensity × 4 weeks × ECE duration. We used the lower bound of the intensity variable and the duration variable to calculate the total dosage variable. For example, if a participant chose "10 to 20 hours" a week for the intensity variable and "3 to 6 months" for the duration variable, then the ECE total dosage = 10 × 4 × 3 = 120 hours. This resulted in a continuous variable of total dosage. In Cambodia, two children were estimated to have attended more than 2000 hours of ECE at five years of age, values which were more than 5 SD from the mean dosage in Cambodia. Since ECE programs in Cambodia are typically 9.5 months a year for 15 hours a week, we replaced the dosage value for these two children with the more realistic value of 1140 hours (2 × 9.5 × 4 × 15 = 1140).

Indices of parental socioeconomic status and household wealth

Family SES is known to be associated with early child development (Richards, Bacon-Shone, & Rao, 2018) and was expected to be associated with the timing and duration of ECE

participation in the sample. Two indices of family SES were generated for this analysis: parental education plus occupation (parental SES) and household wealth. Although these two proxies for SES are correlated (rho = 0.24), the variables were not collapsed because they capture independent variation in the sample; for example, families with high wealth can have low achieved education and work in agriculture. Conversely, families with high achieved education who are office workers may have low household wealth.

The index for parental SES was created using a latent factor measurement model of four variables: maternal and paternal education and occupation. Education was coded as the parent's highest qualification over 8 levels. Occupation was coded over 9 levels. Maternal and paternal occupation and education were assumed to be continuous and were used to create a latent factor score using maximum likelihood estimation allowing for missing values. Scores were subsequently used as a control variable for hierarchical linear modeling **(**HLM) analysis.

The index for household wealth was generated using the first component from a principal components analysis of indicators for household assets, electricity, home, land, and livestock ownership, and having a bank account (Filmer & Pritchett, 2001). This type of wealth index is often used in analyses of child outcomes in both developed and developing country contexts, and commonly adopted in descriptive analyses of Demographic and Health Surveys. Both indices were estimated by country such that a family's score on the index indicates their relative spacing or standing with respect to other parents in the sample in the same county.

Procedure

At least three members of the research team in each country participated in an EAP-ECDS training workshop in February 2013. A university-based technical support team then provided in-country training to administrators on the use of the EAP-ECDS and the caregiver

survey. Particular attention was given to: training assessors to use standardized assessment processes; evaluating inter-assessor reliability; and minimizing bias and errors in the assessment process.

The EAP-ECDS were administered to children by individuals who had experience or training in ECE. Assessors were thoroughly familiar with the test materials and practiced administering and scoring the test under the supervision of an experienced assessor before using the test as a standardized measure. Prior to any test administration, the assessor administered the test and scored the child's performance parallel with the supervisor.

The primary caregivers were also interviewed individually with a structured questionnaire to understand (i) family demographic information; (ii) children's early learning and development; and (iii) children's health and habits in all countries except in China, wherein a parent completed questionnaires in small groups under the supervision of a research assistant who was there to answer queries.

Data Analytic Strategy

Hierarchical linear modeling (HLM) was utilized to evaluate associations between ECE participation, intensity, duration, dosage, and child development across three domains, controlling for possible confounding variables. HLM is a useful analytic strategy when the data are inherently nested or when non-independence of observations is a concern (Ployhart, 2005). We used province as a level-2 variable as there are differences in economic development in provinces across the four countries and level of provincial development could potentially influence child outcomes. The inclusion of province as a level-2 variable therefore adjusts for potential similarities between children residing in the same province. The HLM (where $_i$ = child, $_j$ = province) was specified as follows:

$$\text{Child\_outcomes}_{ij} = \gamma_{00} + \beta_{1j}\,\text{Participation} + \beta_{2j}\,\text{Age Categories} + \beta_{3j}\,\text{Gender} + \beta_{4j}\,\text{Parental SES} + \beta_{5j}\,\text{Household Wealth} + \beta_{6j}\text{Urbanicity} + \mu_{0j} + e_{ij}$$

In this equation, the outcome variable $\text{Child\_outcomes}_{ij}$ represents the country-specific age-adjusted EAP-ECDS score for a specific domain, γ_{00} indicates the intercept of the equation, β_{1j} indicates the association of ECE participation with child outcomes, μ_{0j} indicates variances accounted for at the province level, and e_{ij} is a random error term. The equations for ECE intensity, duration, and dosage are similar to that of the ECE participation equation above, where the participation variable is replaced with intensity and duration variables, respectively. The participation variable was coded as binary. Continuous variables were created to represent intensity (one unit equals one hour of participation per week), duration (one unit equals 9 months of participation) and dosage (one unit equals one thousand hours of participation). In addition, intensity, duration, and dosage were split into categorical variables to investigate whether associations with child development were non-linear. The categorical intensity variable was coded as: (1) fewer than 10 hours; (2) 10 to 20 hours; (3) 20 to 30 hours; (4) 30 to 40 hours; and (5) 40 hours or more. The categorical duration variable was coded as: (1) fewer than 7 months; (2) 7 to 18 months; (3) 19 to 30 months; and (4) 31 or more months. The categorical dosage variable was coded as: (1) fewer than 1,000 hours; (2) 1,000 to 2,000 hours; (3) 2,000 to 3,000 hours; (4) 3,000 to 4,000 hours; and (5) 4,000 hours or more.

Data were analyzed using the statistical software package Stata 13.1, with the multilevel mixed-effects linear regression command. We ran separate regressions for each of the three child outcome domains by changing the dependent variable between the Cognitive Development z-score, the Language and Emergent Literacy z-score, and the Socio-emotional Development z-score. We also ran separate regressions to examine associations for each of the ECE variables:

participation (binary); intensity (continuous); duration (continuous); dosage (continuous); intensity (categorical); duration (categorical); and dosage (categorical). For the continuous variables, we ran each regression once whilst including all countries together, once for three countries excluding China, and then again for each country individually. All children in our sample from China attended ECE, so China was excluded from all regressions that used participation as the ECE variable. The associations of ECE intensity, duration, and dosage were examined for the subset of children who participated in any ECE. We focused on categorical differences in dosage in China and Mongolia only due to increased variation in dosage in these countries. Moderation of ECE participation by age was analyzed by including an interaction between ECE participation (binary) and age (continuous) in separate regressions for each domain, country, and three countries combined (excluding China). To account for the possibility that, in observational studies such as the EAP-ECDS, participant characteristics may influence the likelihood of being exposed to a treatment (in this case ECE participation), we conducted sensitivity analysis of associations between ECE participation (binary) and domain scores using inverse probability weights to create a synthetic sample to test the effect of ECE on domain scores (Austin, 2011).

Handling missing data

In order to minimize introducing bias by excluding children, missing values were imputed for control variables (but not for the main outcome or the indicator of ECE participation; 55 children had missing data on preschool participation and these were excluded from the sample). Missing values for intensity (0.5% missing) and duration (7.5% missing) were replaced with the median value for child age in months and country. For both variables missingness was not associated with developmental scores in any of the domains. Missingness for duration and

intensity was associated with maternal and paternal occupation, with maternal and paternal education, and with the latent factor SES variable derived from these four variables, but not with any other demographic variables. Missing values for individual household assets were set to zero (the question may not have been asked in certain settings where ownership of the asset was highly unlikely). As mentioned previously, the parental SES indicator was computed allowing for missing data. 2% to 9% of values were missing for the four education and occupation variables and values were in some cases missing at random conditional on other variables (missingness for parental education was associated with Language and Emergent Literacy and Socio-emotional Development scores and with preschool attendance; and missingness for both paternal and maternal occupation were associated with preschool attendance). Indicator variables for missing parental education and occupation values were included in all regression analyses. Additionally, indicator variables for imputed values for intensity and duration were included in the regression analyses as potential confounding variables. The sensitivity of our findings was checked by repeating the regressions without these imputed data. We did not use more computationally-intensive methods (such as multiple imputation) to impute data because our data met two key criteria for using simpler methods: having a relatively large sample size (n >= 1,000) and having a small proportion of missing data for each variable (<10%) (Cheema, 2014).

Results

ECE participation

With the exception of China, ECE participation rates varied across countries. Cambodia, Mongolia and Vanuatu had participation rates of 42%, 50%, and 48%, respectively (Table 2). In all four countries, the children who attended ECE went to center-based programs, typically kindergartens. There were urban-rural differences in participation in Cambodia where children

from urban families were more likely to attend ECE than children from rural families (52% vs. 30%). However, participation rates were about the same in urban and rural areas of Mongolia and Vanuatu. As expected, ECE participation was positively and significantly associated with children's age (mean difference = 3.8 m, $p < .01$) and parental SES (mean difference = 0.78 SD of the index, $p = .03$). However, participation was not significantly associated with the household wealth index in these countries.

The number of hours per week, or intensity, in ECE was largely determined by the country in which a child lived. For example, 87% of children in China attended ECE for 30-40 hours per week, and 79% of children in Cambodia attended for 10-20 hours per week (Table 2). However, there was more variation in the number of months, or duration, that children attended ECE programs across the four countries (Table 2). For instance, in China and Mongolia ECE duration ranged from less than 3 months to more than 37 months, with children spread across all duration categories. In Cambodia duration ranged from less than 3 months to between 31 and 36 months; and in Vanuatu from less than 3 months to 25 to 30 months.

Associations of ECE participation, intensity and duration with developmental scores

Basic descriptive statistics (mean and standard deviation) for the EAP-ECDS scores by ECE participation, intensity, duration and country are presented in Supplementary Table 5.

ECE participation: The crude difference in mean scores between children who attended ECE and those who did not varied from about 7.2 points in Cambodia for Language and Emergent Literacy to 1.7 points in Vanuatu for Socio-emotional Development (results not shown). After adjusting for potential confounding by family SES, wealth, age, urban-rural residence and gender with the HLM regressions, the estimated association of ECE participation with child development was more consistent across countries and domains. EAP-ECDS scores

were country and age-adjusted z-scores re-centered at mean 100, standard deviation 15 points. Children who attended ECE scored 3.6 (*SE* = 1.7), 5.0 (*SE* = 1.7) and 6.2 (*SE* = 2.3) points higher in Cognitive Development than those who did not attend ECE in Cambodia, Mongolia, and Vanuatu, respectively ($p < 0.05$ for all associations). When examining Language and Emergent Literacy, children who attended ECE scored 6.6 (*SE* = 1.6), 5.4 (*SE* = 0.8) and 6.9 (*SE* = 1.4) points higher than those who did not; and on the Socio-emotional Development domain children who attended ECE scored 4.3 (*SE* = 1.2), 4.5 (*SE* = 0.4) and 3.3 (*SE* = 1.4) points higher than those who did not in Cambodia, Mongolia, and Vanuatu, respectively ($p < 0.05$, see Table 3). Estimated coefficients decreased slightly when excluding children with imputed control variables, but all remained significant ($p < 0.05$) with the exception of the association between ECE participation and Socio-emotional Development in Vanuatu. When inverse probability weights were used to test the associations of ECE participation and domain scores in a synthetic sample, all coefficients remained significant ($p < 0.05$) with the exception of the association between ECE and Socio-emotional Development in Vanuatu (Supplementary Table 6).

Next we examined interactions between ECE participation and age. Figure 1 demonstrates that the gap in age-adjusted z-scores between children who did and did not attend ECE widens with age in all three domains, when data for all three countries are combined (unadjusted for confounding). The gap is widest in the Language and Emergent Literacy domain, followed by the Cognitive Development domain. We tested interactions between ECE participation and age for statistical significance across the three countries combined and for each country individually (Supplementary Table 7). After controlling for child and family confounders, older children who did not attend ECE had significantly lower scores than younger children who did not attend ECE in some countries and domains, but no significant differences

by age were found for children who attended ECE. In the Cognitive Development and Language and Emergent Literacy domains across the three countries combined, scores were 0.10 (*SE* = 0.04) and 0.14 (*SE* = 0.04) lower for each additional month of age for those not attending ECE ($p < 0.05$). In Cambodia and Mongolia, scores were 0.20 (*SE* = 0.10) and 0.06 (*SE* = 0.02) lower for each additional month of age in the Language and Emergent Literacy domain for those not attending ECE ($p < 0.05$). No significant interactions between age and ECE participation were found for Vanuatu individually, or for the Socio-emotional Development domain across the three countries. These results were not sensitive to excluding imputed missing values; significance tests on all coefficients (at the 5% level) gave the same results after excluding imputed values.

ECE Intensity: Among children who attended any ECE, there were no statistically significant differences in EAP-ECDS scores by intensity of participation across all four countries combined, or across three countries excluding China, when controlling for potential confounding (Supplementary Table 8). However, in Cambodia individually, an additional hour of ECE was positively associated with Language and Emergent Literacy ($\beta = 0.15$, *SE* = 0.06) and negatively associated with Socio-emotional Development ($\beta = -0.25$, *SE* = 0.08) scores; and in China an additional hour of ECE was negatively associated ($\beta = -0.46$, *SE* = 0.21) with Socio-emotional Development scores (all *ps* < 0.05). In Mongolia, by contrast, an additional hour of ECE was positively associated with Cognitive Development ($\beta = 0.15$, *SE* = 0.06), Language and Emergent Literacy ($\beta = 0.21$, *SE* = 0.05), and Socio-emotional Development ($\beta = 0.22$, *SE* = 0.06) scores (all *ps* < 0.05); and in Vanuatu there were no statistically significant differences in EAP-ECDS scores with increased hours of ECE intensity. When children with imputed values for intensity or control variables were excluded, results remained the same, with the exception of the association between intensity and Cognitive Development in Mongolia, which was no longer

significant (at the 5% level). There were no statistically significant associations between any domain scores and intensity when intensity was analyzed as a categorical variable, either across all four countries combined or across three countries excluding China (Supplementary Table 9).

ECE duration: In all three domains, age-adjusted z-scores across all countries combined increased as ECE duration increased from the lowest level, although there was relatively little variation between about 3 months and 19 months (Supplementary Figure 1, not adjusted for confounding). For children with 20 months duration or above, scores continued to increase in Cognitive Development and Socio-emotional Development, but remained flat and then decreased at higher duration levels in Language and Emergent Literacy (Supplementary Figure 1). These patterns were tested for statistical significance after adjusting for confounding (Supplementary Table 8). An additional 9 months of ECE duration was significantly associated ($p < 0.05$) with increased Cognitive Development scores across all four countries combined ($\beta = 0.11$, $SE = 0.04$), and in China individually ($\beta = 0.18$, $SE = 0.07$). Across three countries excluding China, an additional 9 months of ECE duration was significantly associated with increased Language and Emergent Literacy scores ($\beta = 0.14$, $SE = 0.05$). An additional 9 months of ECE duration was significantly associated ($p < 0.05$) with increased Socio-emotional Development scores in China ($\beta = 0.13$, $SE = 0.04$). Duration was also analyzed across four categories to test if its relation to development scores was non-linear (Supplementary Table 10). Across all four countries combined, compared to children with less than 7 months' ECE: in Cognitive Development there was a significant ($p < 0.05$) and positive association only for the highest duration level of 31 months or more ($\beta = 4.1$, $SE = 1.3$); and in Language and Emergent Literacy there was a significant ($p < 0.05$) and positive association with the 19 to 30 months duration category ($\beta = 2.4$, $SE = 0.6$), but not the highest duration category of 31 months or more. No

significant associations were found for Socio-emotional Development. When imputed values for duration and control variables were excluded, results remained the same with the exception of the association between ECE duration of 31 months or more and Cognitive Development, which was no longer significant (at the 5% level). Across three countries excluding China there was a significant and positive association for the highest duration level of 31 months or more in Language and Emergent Literacy (β = 5.6, *SE* = 2.0), and a negative association for 19 to 30 months duration in Socio-emotional Development (β = -3.6, *SE* = 1.2).

ECE dosage: Table 4 shows that an additional 1,000 hours of ECE participation was associated (*ps* < 0.05) with: increased Cognitive Development scores in China (β = 1.5, *SE* = 0.6), Mongolia (β = 0.5, *SE* = 0.2), and across all four countries combined (β = 0.9, *SE* = 0.3); increased Language and Emergent Literacy scores in Cambodia (β = 4.6, *SE* = 1.5), Mongolia (β = 1.2, *SE* = 0.5), and across three countries excluding China (β = 1.0, *SE* = 0.4); and with increased Socio-emotional Development scores in China (β = 0.9, *SE* = 0.3) but decreased Socio-emotional Development scores in Cambodia (β = -5.7, *SE* = 2.1). When imputed values were excluded, the positive association between additional dosage and Cognitive Development in Mongolia was no longer significant (at the 5% level). However, in Vanuatu the coefficients for Cognitive Development and Language and Emergent Literacy were larger, positive and significant (p < 0.05).

We examined these associations across different categories of dosage to test for non-linearity (Figure 2). This was conducted in China and Mongolia only due to relatively low levels of dosage in Cambodia and Vanuatu. Compared to a dosage of less than 1,000 hours: in Cognitive Development there was a positive association (all *ps* < 0.05) with 4,000 hours or more in China (β = 6.6, *SE* = 2.2), and with 3,000 to 4,000 hours in Mongolia (β = 2.7, *SE* = 1.0); in

Language and Emergent Literacy there was a positive association with 2,000 to 3,000 hours in China ($\beta = 2.5$, $SE = 0.7$) and over 4,000 hours in Mongolia ($\beta = 4.2$, $SE = 1.0$); and in Socio-emotional Development there was a positive association with 2,000 to 3,000 ($\beta = 2.9$, $SE = 0.8$), and over 4,000 hours ($\beta = 4.3$, $SE = 0.9$) in China, but no significant association (at the 5% level) in Mongolia. When imputed values were excluded: there was a significant positive association between 1,000 to 2,000 hours duration and Cognitive Development in China; and there was a significant positive association between a duration of 4,000 or more hours and Cognitive Development in Mongolia ($p < 0.05$). However, the associations between 3,000 to 4,000 hours duration and Cognitive Development in Mongolia, and between 2,000 to 3,000 hours duration and Language and Emergent Literacy in China, were no longer significant (at the 5% level). Supplementary Table 11 shows the proportion of total variance at level 2 for each model reported in Tables 3 and 4 and in Figure 2.

Discussion

This study examined the association between ECE participation and quantity and child development across four countries in East Asia and the Pacific as measured by the EAP-ECDS, a recently developed, psychometrically robust and culturally valid regional tool. Using data from Cambodia, China, Mongolia, and Vanuatu, which includes a large and diverse population of children from both urban and rural areas, this study adds to the limited body of research regarding the influence of ECE programs on developmental outcomes among children in LMIC. Findings reflect a strong and consistent positive association between ECE program participation and developmental scores among children in the four countries, though the strength of the associations with ECE quantity varied, and in some cases, no associations were observed. Overall, findings from the current study are consistent with previous research in high income and

LMIC demonstrating that ECE has a positive influence on early child development (Melhuish et al., 2015).

ECE participation and child outcomes

After controlling for children's age, gender, parental SES, household wealth and urbanicity, ECE participation was found to be significantly and positively related to children's Cognitive Development, Language and Emergent Literacy, and Socio-emotional Development with a similar magnitude of associations in the three countries included in the analysis (Cambodia, Mongolia, and Vanuatu). These results are consistent with previous research which suggests that children in LMIC who participate in some form of ECE have better developmental functioning than those who do not (Aboud, 2006; Rao et al., 2012). The modest magnitude of the association (5 points or a third of a standard deviation) may have been limited by low participation rates, short attendance duration and potentially lower quality of ECE provision. Nevertheless, these results provide stronger evidence regarding the benefits of ECE participation relative to prior studies as they demonstrate gains across multiple key domains of children's development compared to those not participating in ECE.

Wong, Luo, Zhang and Rozelle (2013) found that a voucher scheme/conditional cash transfer in rural China boosted children's preschool participation but that preschool participation was not associated with children's school readiness. The authors attribute the latter to the low quality of preschool in rural Henan province. The sample for the present study did not include children in China who did not attend ECE, so direct comparisons with the Wong et al. study are not possible for China. However, low quality of ECE may be a possible explanation for why the associations found in Cambodia, Mongolia and Vanuatu were relatively modest.

ECE intensity and child outcomes

ECE intensity was not associated with children's overall development after controlling for child and family level confounders, with the data from all countries combined. When countries were analyzed individually, positive associations were found between increased intensity and all three developmental domains in Mongolia, and for Language and Emergent Literacy in Cambodia. However, we found negative associations between increased intensity and Socio-emotional Development in Cambodia and China.

These inconsistent results across the different countries in our sample suggest that the relation between ECE intensity and Socio-emotional Development is complex. We did not collect data on ECE quality or garner details about children's ECE learning activities during that time. Hence these findings, on the one hand, might reflect variations in ECE quality. On the other hand, they may also reflect the fact that context-specific factors influence the relation between ECE intensity and Socio-emotional Development. A positive relation between the two variables was found in Mongolia, a country with a large nomadic population and mobile kindergartens that follow the seasonal pattern of movements of families. In this context, the consistent exposure to a stable organized learning environment (compared to the changing physical environment) may benefit Mongolian children's socio-emotional development. In contrast, Chinese children typically attend ECE for 31 to 40 hours every week, but we found that spending more than 40 hours a week in ECE was associated with poorer Socio-emotional Development. Further research is needed to better understand the reasons behind these findings in China. For example, they may be due to long periods of time in large group settings, the low quality of ECE, and/or limited quality time spent with parents.

It should be noted that studies conducted in some high income countries also report mixed findings on the relation between the quantity of ECE and children's behavioral outcomes.

Some studies have reported that ECE intensity is associated with greater gains in reading and mathematics skills (Votruba-Drzal, Li-Grining, & Maldonado-Carreño, 2008), socio-emotional development, language and math skills as well as physical health (Reynolds et al, 2004), cognitive achievement (Walters, 2014), and literacy skills (Gibbs, 2014). However, other studies suggest that, in addition to improved academic outcomes, ECE intensity has also been linked with increased behavioral difficulties (e.g., Gibbs, 2014; Loeb et al., 2007; Votruba-Drzal, Li-Grining, & Maldonado-Carreño, 2008; Walters, 2014).

ECE duration and child outcomes

Consistent with prior research (Biedinger et al., 2008; Domitrovich et al, 2013; Skibbe et al, 2011), we found that ECE duration was positively associated with children's Cognitive Development after controlling for potential confounders at the regional level (data from all four countries combined) and for China (when data from four countries were analyzed separately). There were also non-linear associations between ECE duration and child performance in Cognitive Development and Language and Emergent Literacy. These indicated that the positive associations between ECE and Cognitive Development were likely to occur when children were enrolled in ECE for a relatively long time (31 months or more); but that a positive association between ECE and Language and Emergent Literacy was found for a duration of 19 to 30 months, but not for 31 months or more. These results support previous findings regarding the influence of quantity of ECE participation on child outcomes and suggest that 31 months or more of ECE is necessary for benefits to be apparent in children's cognitive development but participation between 19 and 30 months suffices for gains in language development. This could be because children's home learning environments are more likely to support the development of language skills than the cognitive skills assessed in the EAP-ECDS but this speculation is beyond what is

warranted by the data as we did not control for program quality and other parameters that would be key to such an analysis.

ECE total dosage and child outcomes

ECE total dosage was also found to significantly predict child outcomes with an additional 1000 hours of participation associated with an increase in Cognitive Development at the regional level and for China and Mongolia; an increase in Language and Emergent Literacy for Cambodia and Mongolia; and with an increase in Socio-emotional Development for China. In contrast, a negative association was found in Socio-emotional Development for Cambodia with an increase of 1000 hours of participation. Further examinations comparing non-linear associations of different dosages suggested that children were likely to benefit more from a relatively large amount of total exposure in ECE than the basic amount of exposure, at least when quality was not considered. The results strengthen the importance of increased ECE dosage for better child outcomes in LMIC and further the argument of "something is better than nothing" in LMIC where ECE quality is a common concern (Rao et al., 2012). Compared to experiencing low levels of learning stimulation at home, more exposure in structured ECE programs has been demonstrated to be beneficial for early child development. Few studies have reported on the effects of cumulative ECE dosage (Wasik & Snell, 2015), and as such the current study provides an important insight into how much ECE is beneficial for child development. That stated, more attention needs to be paid to the content and quality of the ECE provision in developing countries considering the small coefficient sizes detected.

Taken together, the analyses on the associations between (i) ECE participation; (ii) ECE intensity; (iii) ECE duration; and (iv) ECE total dosage and early development in Cognitive Development, Language and Emergent Literacy, and Socio-emotional Development generally

suggest the benefits of participation in ECE programs for a relatively longer time and starting from an early age. However, it should be kept in mind that the analyses of each particular ECE quantity parameter were conducted without considering influences of other parameters. For each individual child, it is impossible to disentangle early experiences in ECE programs into segments of ECE intensity alone, ECE duration alone, and total dosage, as these different parameters of ECE quantity together all influence child development. Although the current study provides an important step forward in exploring the influence of ECE dose on children's outcomes, further studies are needed to shed light on the optimal combination of ECE quantity to provide children of different ages and from different backgrounds.

Moderating variables

The results of the analyses with combined data from Cambodia, Mongolia and Vanuatu further indicate that child age may moderate the association between ECE participation and child development in Language and Emergent Literacy and Cognitive Development. As children mature, there is a widening gap between children who attend ECE compared to their same-age and same-country peers who do not. Similar trends are identified in country-specific analyses: the difference in Language and Emergent Literacy scores between younger and older children who do not attend ECE is statistically significant in Cambodia and Mongolia. Different interpretations of this finding are plausible. It could suggest that ECE participation is most beneficial for slightly older children considering, for those not attending ECE, age-adjusted z-scores of older children are on average lower than that for younger children. However, these results may also reflect a cumulative disadvantage for older children who have consistently not attended ECE. More research using longitudinal data would be beneficial to address this question. Loeb et al. (2007) examined reading and math scores among children in the U.S. and reported

that the greatest academic benefits of ECE were found for children who commenced ECE at ages 2-3 years, relative to children of other ages. It is not clear as to whether our findings on interactions between participation and age are consistent or inconsistent with the recommendations from Loeb et al. (2007). However, given that we also found significant associations between ECE duration and developmental scores, it is perhaps more likely that differences by age reflect a cumulative disadvantage associated with a lack of ECE participation, rather than ECE being most beneficial at older ages.

Implications

The results contribute to the accumulating evidence for the support of the importance of ECE, a distinct proximal environment in early child development, in children's Cognitive Development, Socio-emotional Development, and Language and Literacy Development in LMIC. In particular, the results shed light on the understanding on the associations between the quantity of ECE exposure and early child development with nuanced examinations from the perspectives of ECE intensity, duration, and total dosage, respectively. This is innovative given the complexity of ECE exposure in LMIC. Although the particular relations between different aspects of ECE quantity and early child development vary, participation in quality ECE with sufficient quantity and at an appropriate age show universal benefits for early child development across countries and contexts in the sample.

These findings are all significant to policy across East Asia and the Pacific, and indeed LMIC more broadly. Results suggest that efforts to ensure all children have access to quality ECE be employed, which will involve exploring and reducing known barriers to participation as well as further work investigating program quality, so that these developmental benefits can be maximized across the region.

Our findings suggest that ECE intensity, duration and dosage are all positively associated with Cognitive Development and Language and Emergent Literacy, but that intensity and dosage can in some cases also be negatively associated with children's Socio-emotional Development scores. Additional analyses considering country-specific factors may be able to reveal a more nuanced interpretation of these findings, and as such could also lead to additional country-specific policy recommendations.

Limitations

Several limitations should be taken into account when interpreting the findings of this study. First, although a stratified sample was used, strictly speaking the sample was not a representative sample – for instance due to the selection of five specific provinces in China, and the exclusion of ethnic minorities - and thus the generalization of findings is limited. Generalization is also limited by the fact that the final analytic sample differed from the original representative sample to some extent, with 122 children excluded (of which 106 were from Vanuatu), which limits the representativeness of the findings (in Vanuatu in particular). Second, due to the cross-sectional study design, as with the majority of research into the influence of ECE, the data cannot provide unequivocal evidence of causal direction. Future longitudinal research could not only reveal causal relations but also elucidate the developmental changes and patterns of child development in relation to ECE participation in developing countries. Third, there may well be unobserved confounds that influence both ECE and child development and, to the extent that this is true, these could explain part of the associations found. Fourth, data were not collected on pre-assessment of children's cognitive, language, and socio-emotional development before participation in ECE, so it was not possible to control for differences in abilities before ECE participation. Fifth, data on duration and intensity were in categories rather

than reported as continuous variables, which limits the precision of the measures of duration, intensity and dosage, and – particularly for the intensity measure – there was limited variation between categories in some countries. Further, the measure of ECE duration is based on a question asking how long children have been in "this" program, and therefore may underestimate duration for children who switched from one program to another. Finally, given that the teaching content and quality are important elements of ECE, and that low quality ECE may produce either no benefit or negative effects on child development (Melhuish et al., 2015; Wasik & Snell, 2015), the current study is limited by the fact that both ECE content and quality were not measured or included in analyses. Future studies should further explore the impacts of ECE teaching content and quality on child development as measured by the EAP-ECDS.

Conclusion

The present study adds to the limited body of research on the influence of ECE experience and quantity on early childhood development in LMIC. ECE participation, duration and total dosage were all associated with positive child development. Based on the findings of this study, policy makers should work to ensure that *all* children across East Asia and the Pacific have access to quality ECE, which will require further investigation into both program quality as well as how barriers to program access can be addressed effectively across the region.

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Table 1

Composition of the sample, by country, gender, and urbanicity

Country	Rural		Urban		Total
	Female	Male	Female	Male	
Cambodia	270	273	324	322	1189
China	400	422	404	392	1618
Mongolia	301	306	311	312	1230
Vanuatu	287	320	39	29	675
Total	1258	1321	1078	1055	4712

Table 2

Frequency and Proportion of ECE participation, intensity, and duration by country*

Question	Response Options	Cambodia	China	Mongolia	Vanuatu
ECE participation	a) No	690 (0.58)	(0)	611 (0.5)	354 (0.52)
	b) Yes	499 (0.42)	1618 (1)	619 (0.5)	321 (0.48)
ECE intensity	a) less than 10 h	56 (0.11)	(0)	8 (0.01)	158 (0.49)
	b) 11 to 20 h	392 (0.79)	(0)	3 (0)	128 (0.4)
	c) 21 to 30 h	36 (0.07)	(0)	8 (0.01)	12 (0.04)
	d) 31 to 40 h	11 (0.02)	1405 (0.87)	321 (0.52)	21 (0.07)
	e) more than 40 h	4 (0.01)	213 (0.13)	279 (0.45)	2 (0.01)
ECE duration	a) less than 3 m	34 (0.07)	359 (0.22)	6 (0.01)	19 (0.06)
	b) 3 to 6 m	90 (0.18)	158 (0.1)	21 (0.03)	112 (0.35)
	c) 7 to 12 m	320 (0.64)	224 (0.14)	153 (0.25)	160 (0.5)
	d) 13 to 18 m	29 (0.06)	327 (0.2)	133 (0.21)	19 (0.06)
	e) 19 to 24 m	19 (0.04)	209 (0.13)	126 (0.2)	5 (0.02)
	f) 25 to 30 m	5 (0.01)	218 (0.13)	99 (0.16)	6 (0.02)
	g) 31 to 36 m	2 (0)	95 (0.06)	64 (0.1)	(0)
	h) more than 37 m	(0)	28 (0.02)	17 (0.03)	(0)

* Distribution data are N (proportion) by response option and country
Question posed to all parents:
ECE participation: Has your child ever attended any organized learning or early childhood education program, such as a private or government facility, including kindergarten or community childcare or drop-in center?
Questions posed to those who ever attended:
ECE intensity: How many hours a week does your child attend the program?
ECE duration: How long has your child been in this program?

Table 3

Estimated association of ECE participation with EAP-ECDS scores, by domain

	Three countries excluding China	**Cambodia**	**Mongolia**	**Vanuatu**
	β (SE)	*β (SE)*	*β (SE)*	*β (SE)*
Participation: Cognitive Development				
ECE participation vs none	4.825* (1.01)	3.575* (1.74)	5.018* (1.67)	6.161* (2.30)
Sex (male)	-1.225* (0.42)	-0.25 (0.85)	-2.096* (0.48)	-1.905 (1.32)
Parental SES	1.769* (0.62)	0.696 (0.90)	3.268* (0.43)	-1.797* (0.77)
Wealth	0.493* (0.22)	0.630 (0.44)	0.636 (0.34)	0.507 (0.30)
Urban residence	3.076 (2.14)	4.300 (2.50)	-1.075 (1.52)	3.269 (3.81)
Participation: Language and Emergent Literacy				
ECE participation vs none	5.996* (0.70)	6.637* (1.59)	5.405* (0.78)	6.917* (1.42)
Sex (male)	-3.414* (0.61)	-1.313* (0.66)	-5.374* (0.47)	-3.862* (1.28)
Parental SES	1.680* (0.75)	0.228 (1.21)	3.080* (0.29)	-0.132 (1.29)
Wealth	0.825* (0.25)	1.007* (0.32)	1.201* (0.47)	0.291 (0.24)
Urban residence	1.164 (1.66)	0.311 (2.43)	0.288 (2.26)	5.015 (3.01)
Participation: Socio-emotional Development				
ECE participation vs none	4.091* (0.41)	4.266* (1.18)	4.494* (0.40)	3.252* (1.39)
Sex (male)	-1.827* (0.50)	-1.938 (1.24)	-1.901* (0.57)	-1.730* (0.86)
Parental SES	1.420* (0.69)	0.444 (1.61)	2.349* (0.36)	0.540 (0.37)
Wealth	0.586* (0.29)	0.435 (0.55)	0.937* (0.30)	0.638 (0.42)
Urban residence	2.736 (2.61)	2.109 (3.71)	1.539 (2.81)	6.900 (3.93)

* $p < .05$. EAP-ECDS scores are country and age-adjusted z-scores re-centered at mean 100, standard deviation 15 points.

Table 4

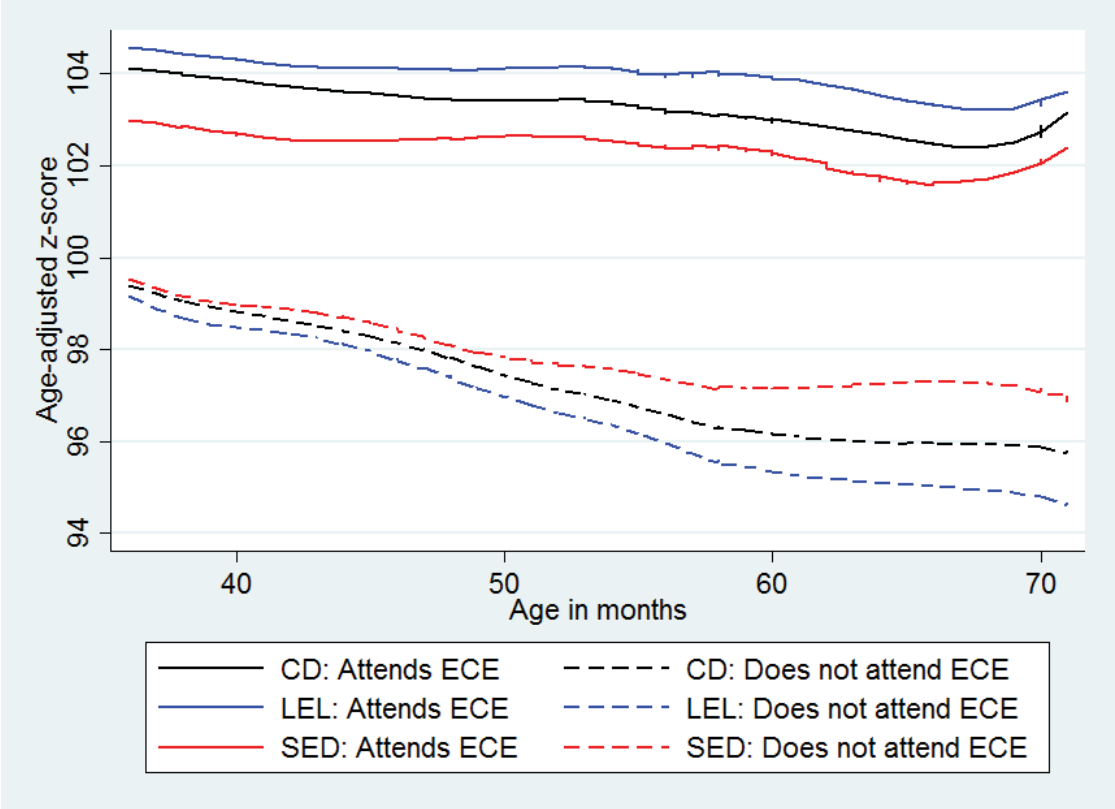
Estimated association of ECE dosage (hours) and EAP-ECDS scores

	All four countries	**Three countries excluding China**	**Cambodia**	**China**	**Mongolia**	**Vanuatu**
	β (SE)	*β (SE)*	*β (SE)*	*β (SE)*	*β (SE)*	*β (SE)*
Dosage: *Coefficient for each additional **1000 h** of ECE participation*						
Cognitive Development	0.897* (0.34)	0.379 (0.29)	-3.584 (3.29)	1.473* (0.57)	0.487* (0.24)	4.564 (2.97)
Language and Emergent Literacy	0.382 (0.37)	1.042* (0.35)	4.607* (1.45)	0.022 (0.51)	1.150* (0.46)	2.985 (2.09)
Socio-emotional Development	0.378 (0.23)	0.034 (0.35)	-5.678* (2.12)	0.850* (0.27)	-0.01 (0.35)	1.058 (3.56)

* $p < .05$. EAP-ECDS scores are country and age-adjusted z-scores re-centered at mean 100, standard deviation 15 points.

Figure 1

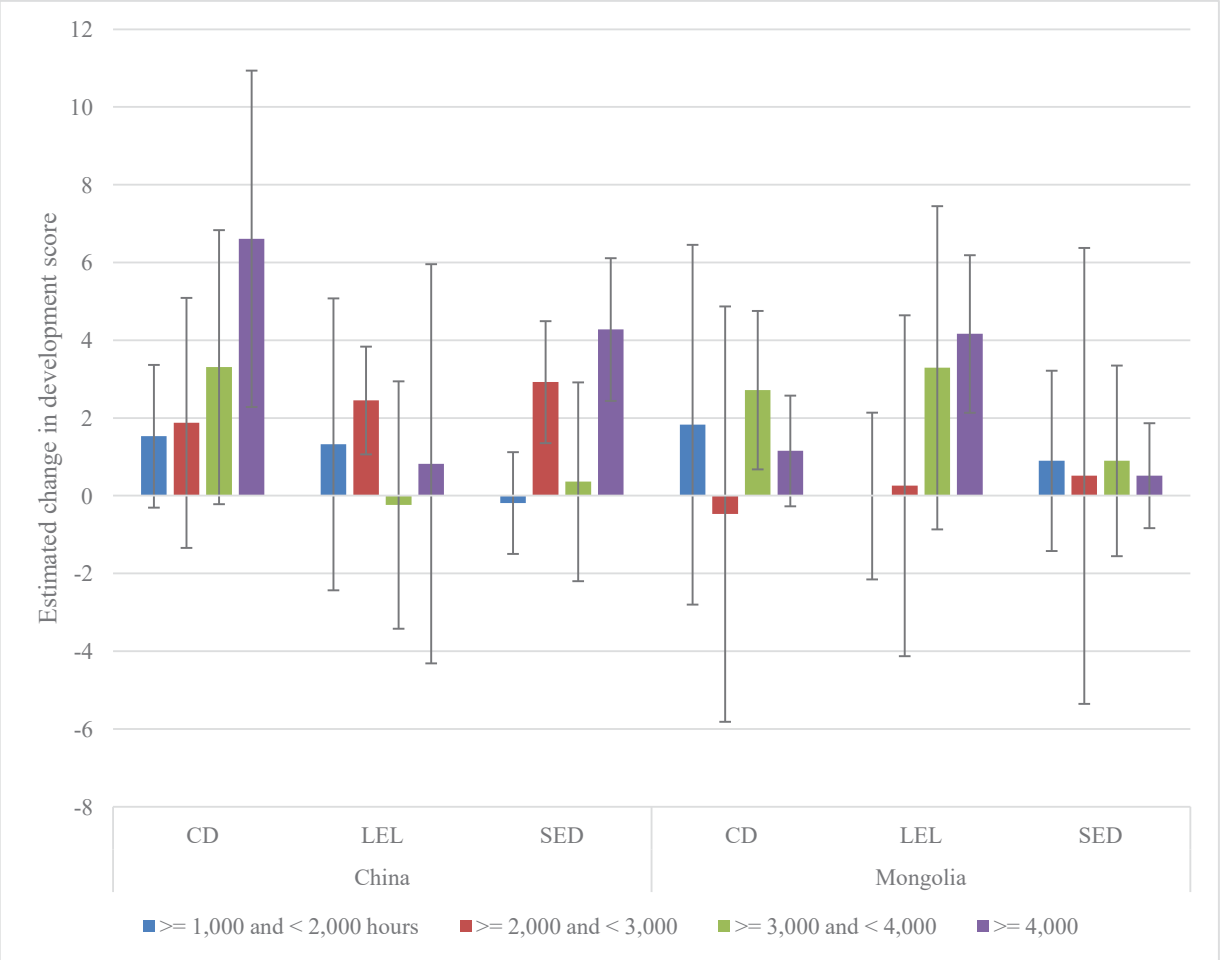
Change in age-adjusted domain-specific z-scores by ECE participation in 3 countries: Cambodia, Mongolia, and Vanuatu (excludes China)



Note: Figure 1 shows descriptive statistics of age-adjusted country-specific domain z-scores for children of different ages, by whether or not the child attends preschool. A running mean procedure was applied to the data.

Figure 2

Associations between ECE dosage (hours, compared to < 1,000) and development scores across three domains (China and Mongolia only)



Note: The three domains are Cognitive Development (CD) Language and Emergent Literacy (LEL), and Socio-emotional Development (SED). Error bars show 95% confidence intervals.

Supplementary Table 1

A summary of related studies on ECE intensity and duration

Author(s)	Country	Findings
ECE intensity		
Loeb et al., 2007	United States	Using data from the Early Childhood Longitudinal Study (N=14,162), this study found that more hours of center-based care were associated with greater social competencies and academic benefits, such as reading and math skills among five year olds.
Votruba-Drzal, Li-Grining, & Maldonado-Carreño, 2008	United States	Using data from Welfare, Children, and Families: AThree-City Study (N=204), this study found that extensive hours in child care were associated with gains in quantitative skills and socioemotional skills among low-income children aged two to four.
Reynolds et al., 2014	United States	In a study with 982 three and four year old low-income, ethnic minority children, full day preschool (7 hours) participants had higher school readiness in socio-emotional development, language, mathematics and physical health than those who attended half-day programs (3 hours).
Walters, 2014	United States	Using data from the Head Start Impact Study (N=4,442), head start center offering full day programs boosted cognitive skills among 3- and 4-year-olds.
ECE duration		
Skibbe et al., 2011	United States	Children (N=76) who experienced two years of preschool predicted grated gains in early literacy skills, such as decoding and letter knowledge.
Domitrovich et al, 2013	United States	Children from low-income backgrounds (N=116) who experienced two years of preschool had greater gains in school readiness skills, such as literacy and numeracy than those who experienced only one year of preschool (N=116).
Biedinger, Becker & Rohling, 2008	Germany	Using the school entrance examination data for 2000-2005 among 6777 6- and 7 year old children, the study found that preschool attendance was associated with increased school readiness skills. Immigrant children benefited from preschool attendance that was longer than two years.
Arteaga, Humpage, Reynolds & Temple, 2013	United States	Using data with 1500 children from the Chicago Longitudinal Study, children who attended preschool for two years were less likely to receive special education, commit crime or be abused or neglected

Supplementary Table 2

Context information for four countries

	Cambodia	China	Mongolia	Vanuatu
Country population 2016 (‘000)	15,827	1,382,323	3,006	270
GDP Per Capita Income 2014 (current US$)	1,095	7,590	4,129	3,148
% of children under age 5 suffering from moderate or severe stunting 2009-2014	32	9	11	29
Population below $1.90 a day (2003-2013) (%)	6.2	11.2	0.4	15.4
GER in Pre-Primary Education 2014 (%)	18	82	86	97

Source: UNESCO (2016). *Global Education Monitoring Report 2016, Education for people and the planet: Creating Sustainable Futures for All*. Paris: UNESCO.

Supplementary Table 3

Number of children per province, by country

Province number	Cambodia	China	Mongolia	Vanuatu	Total
1	96	0	0	0	96
2	382	0	0	0	382
3	70	0	0	0	70
4	120	0	0	0	120
5	119	0	0	0	119
6	48	0	0	0	48
7	142	0	0	0	142
8	48	0	0	0	48
9	70	0	0	0	70
10	94	0	0	0	94
11	0	216	0	0	216
12	0	315	0	0	315
13	0	393	0	0	393
14	0	379	0	0	379
15	0	315	0	0	315
16	0	0	156	0	156
17	0	0	153	0	153
18	0	0	145	0	145
19	0	0	155	0	155
20	0	0	621	0	621
36	0	0	0	102	102
37	0	0	0	124	124
38	0	0	0	115	115
39	0	0	0	103	103
40	0	0	0	97	97
41	0	0	0	134	134
Total	1,189	1,618	1,230	675	4,712

Supplementary Table 4

Items for each domain of the EAP-ECDS

Domain	Description	Items	Competencies assessed
Cognitive Development	Number sense Concept formation Simple categorization Short-term memory	21	Counting Addition/Subtraction Short-term memory Concepts and Behavioural inhibition Knowledge of shapes
Socio-emotional Development	Ability to label emotions Social understanding Methods of conflict resolution	15	Etiquette Social comprehension Emotional recognition Perspective taking
Motor Development	Fine and gross motor skills	7	Fine and gross motor control
Language and Emergent Literacy	Understanding, speaking and early reading and writing skills	16	Expressive language Grapheme knowledge Writing/drawing
Health, Hygiene and Safety	Daily habits to protect health Unsafe practices Hygiene-related behaviours	9	Hygiene Safety Named body parts Food safety
Cultural Knowledge and Participation	Cultural knowledge Participation in culturally relevant activities	10	Knows local customs Knows local songs
Approaches to Learning	Executive Functions Persistence Interest	7	Behavioural inhibition Cognitive flexibility Engagement

Supplementary Table 5

Mean and SD of EAP-ECDS scores by ECE participation, intensity, duration, and country*

Question	Response options	Domain	Cambodia		China		Mongolia		Vanuatu	
ECE participation	a) No	CD	98.3	(14.5)			96.5	(14.8)	97.1	(13.3)
		LEL	97.1	(14.2)			96.2	(15.3)	97.5	(13.9)
		SED	98.3	(14.7)			97.0	(14.6)	98.9	(14.5)
	b) Yes	CD	102.7	(14.6)	100.1	(14.8)	103.5	(13.9)	103.1	(15.2)
		LEL	104.3	(14.5)	100.1	(14.7)	103.7	(13.3)	103.6	(14.3)
		SED	102.5	(14.4)	100.1	(14.7)	102.9	(14.4)	100.7	(14.0)
ECE intensity	a) less than 10 h	CD	107.3	(12.2)			104.2	(10.9)	103.8	(14.6)
		LEL	100.0	(14.4)			95.9	(11.9)	105.4	(14.6)
		SED	108.4	(12.3)			106.1	(9.4)	101.7	(14.3)
	b) 10 to 20 h	CD	102.1	(14.7)			95.5	(18.2)	101.3	(15.6)
		LEL	104.4	(14.2)			108.2	(3.4)	99.8	(13.1)
		SED	101.8	(14.3)			100.3	(8.6)	97.7	(12.8)
	c) 20 to 30 h	CD	102.4	(15.7)			91.0	(14.2)	105.0	(13.4)
		LEL	106.0	(15.7)			98.7	(12.9)	110.3	(13.9)
		SED	102.2	(14.1)			98.7	(18.6)	104.8	(14.4)
	d) 30 to 40 h	CD	105.2	(15.0)	100.7	(14.3)	103.3	(14.3)	108.2	(18.1)
		LEL	112.8	(17.7)	100.7	(14.1)	102.9	(13.7)	108.2	(14.7)
		SED	101.8	(22.5)	101.0	(14.5)	100.2	(14.5)	107.8	(15.3)
	e) more than 40 h	CD	97.4	(2.2)	95.6	(16.8)	104.2	(13.3)	96.7	(2.5)
		LEL	112.6	(10.0)	96.4	(17.5)	105.0	(12.8)	112.9	(9.5)
		SED	95.2	(7.0)	94.3	(14.6)	106.2	(13.8)	104.8	(8.9)

ECE duration	a) less than 3 m	CD	105.8	(13.4)	99.1	(15.6)	97.9	(11.9)	101.9	(14.6)
		LEL	103.5	(13.5)	99.4	(15.0)	101.2	(18.0)	102.9	(18.9)
		SED	106.6	(15.4)	99.0	(14.6)	99.7	(21.9)	103.0	(17.4)
	b) 3 to 6 m	CD	107.8	(14.6)	100.1	(14.1)	104.3	(12.5)	104.3	(16.1)
		LEL	105.6	(14.0)	100.6	(15.3)	103.8	(14.2)	102.2	(13.6)
		SED	105.7	(15.6)	101.0	(15.1)	102.9	(11.9)	100.0	(12.6)
	c) 7 to 12 m	CD	100.4	(14.2)	99.1	(15.9)	103.4	(14.5)	104.2	(15.2)
		LEL	103.2	(14.7)	100.9	(15.0)	103.4	(13.6)	105.8	(14.1)
		SED	100.8	(13.9)	99.4	(14.6)	103.7	(14.5)	102.3	(14.7)
	d) 13 to 18 m	CD	104.8	(11.3)	99.2	(14.9)	103.4	(14.1)	91.6	(7.6)
		LEL	108.2	(12.5)	99.0	(14.4)	101.5	(13.8)	94.7	(12.0)
		SED	103.7	(11.8)	98.7	(14.8)	103.3	(15.4)	93.5	(10.7)
	e) 19 to 24 m	CD	108.8	(18.5)	101.5	(13.4)	101.3	(13.2)	100.4	(11.2)
		LEL	108.4	(15.6)	102.9	(13.4)	102.9	(12.4)	105.6	(14.5)
		SED	107.4	(13.3)	103.1	(13.6)	99.8	(12.9)	95.3	(9.7)
	f) 25 to 30 m	CD	100.9	(18.3)	100.5	(13.6)	104.2	(15.4)	93.5	(7.2)
		LEL	113.7	(14.7)	100.2	(14.6)	104.9	(13.8)	97.1	(9.0)
		SED	96.7	(20.3)	99.9	(14.6)	103.2	(15.6)	91.4	(5.7)
	g) 31 to 36 m	CD	116.0	(2.2)	104.4	(15.1)	106.7	(11.2)		
		LEL	117.4	(1.9)	98.8	(14.0)	107.7	(10.8)		
		SED	106.0	(1.2)	101.7	(15.2)	105.9	(12.4)		
	h) more than 37 m	CD			102.1	(11.7)	106.0	(13.8)		
		LEL			95.6	(15.4)	108.6	(12.3)		
		SED			104.4	(15.7)	105.1	(14.8)		

* Scores are country and age-adjusted z-scores re-centered at mean 100, standard deviation 15 points, but are not statistically adjusted for possible confounding factors. Scores are provided for three domains: Cognitive Development (CD); Language and Emergent Literacy (LEL); and Socio-emotional Development (SED).

Supplementary Table 6

Estimated association of ECE participation with EAP-ECDS scores, by domain, using inverse probability weighting

	Three countries excluding China	**Cambodia**	**Mongolia**	**Vanuatu**
	β (SE)	*β (SE)*	*β (SE)*	*β (SE)*
Attendance: Cognitive Development				
ECE participation vs none	5.292*	3.491*	4.363*	6.758*
	(0.57)	(1.13)	(1.09)	(1.15)
Attendance: Language & Emergent Literacy				
ECE participation vs none	6.164*	6.120*	4.668*	6.733*
	(0.55)	(1.08)	(1.25)	(1.15)
Attendance: Socio-emotional Development				
ECE participation vs none	3.543*	4.205*	3.639*	2.199
	(0.56)	(1.15)	(1.03)	(1.16)

* $p < .05$. EAP-ECDS scores are country and age-adjusted z-scores re-centered at mean 100, standard deviation 15 points.

Supplementary Table 7

Estimated association of ECE participation and age interactions with EAP-ECDS scores, by domain

	Three countries excluding China	**Cambodia**	**Mongolia**	**Vanuatu**
	β (SE)	*β (SE)*	*β (SE)*	*β (SE)*
Participation x Age in months: Cognitive Development				
Coefficient for increasing age in months when attending ECE	-0.014 (0.04)	-0.052 (0.05)	0.040 (0.06)	-0.036 (0.11)
Coefficient for increasing age in months when not attending ECE	-0.103* (0.04)	-0.115 (0.07)	-0.052 (0.06)	-0.148 (0.11)
Participation x Age in months: Language & Emergent Literacy				
Coefficient for increasing age in months when attending ECE	-0.023 (0.04)	-0.084 (0.09)	0.041 (0.03)	-0.074 (0.09)
Coefficient for increasing age in months when not attending ECE	-0.136* (0.04)	-0.204* (0.10)	-0.061* (0.02)	-0.196 (0.10)
Participation x Age in months: Socio-emotional Development				
Coefficient for increasing age in months when attending ECE	-0.01 (0.05)	-0.046 (0.06)	0.027 (0.09)	-0.03 (0.11)
Coefficient for increasing age in months when not attending ECE	-0.085 (0.05)	-0.119 (0.08)	-0.057 (0.09)	-0.092 (0.13)

* $p < .05$. EAP-ECDS scores are country and age-adjusted z-scores re-centered at mean 100, standard deviation 15 points.

Supplementary Table 8

Estimated association of EAP-ECDS scores and (i) ECE intensity (hours) and (ii) ECE duration (months)

	All four countries	**Three countries excluding China**	**Cambodia**	**China**	**Mongolia**	**Vanuatu**
	β (SE)	*β (SE)*	*β (SE)*	*β (SE)*	*β (SE)*	*β (SE)*
Intensity: *Coefficient for each additional **1 hour per week** of ECE participation*						
Cognitive Development	-0.055 (0.07)	0.028 (0.05)	-0.145 (0.08)	-0.126 (0.10)	0.151* (0.06)	0.161 (0.10)
Language & Emergent Literacy	-0.001 (0.05)	0.061 (0.05)	0.153* (0.06)	-0.054 (0.10)	0.206* (0.05)	0.084 (0.09)
Socio-emotional Development	-0.097 (0.10)	0.023 (0.08)	-0.245* (0.08)	-0.459* (0.21)	0.220* (0.06)	0.129 (0.13)
Duration: *Coefficient for each additional **9 months** of ECE participation*						
Cognitive Development	0.106* (0.04)	0.028 (0.05)	-0.144 (0.25)	0.178* (0.07)	0.054 (0.04)	0.015 (0.27)
Language & Emergent Literacy	0.048 (0.06)	0.144* (0.05)	0.150 (0.10)	-0.012 (0.08)	0.151 (0.09)	0.107 (0.19)
Socio-emotional Development	0.044 (0.04)	-0.050 (0.04)	-0.147 (0.13)	0.126* (0.04)	-0.065 (0.08)	-0.174 (0.17)

* $p < .05$. EAP-ECDS scores are country and age-adjusted z-scores re-centered at mean 100, standard deviation 15 points.

Supplementary Table 9

Estimated association of ECE intensity (hours) and EAP-ECDS scores by intensity category, compared to under 10 hours (all four countries combined, and three countries excluding China)

	10 to 20 hours *β (SE)*	**20 to 30 hours** *β (SE)*	**30 to 40 hours** *β (SE)*	**40+ hours** *β (SE)*
All four countries combined				
Cognitive Development	-0.745 (1.67)	-2.566 (2.19)	-0.569 (2.25)	-1.443 (2.56)
Language & Emergent Literacy	-0.498 (1.7)	-0.081 (1.59)	-0.889 (1.85)	-0.523 (2.20)
Socio-emotional Development	-2.152 (1.47)	-2.779 (1.72)	-3.301 (2.01)	-4.140 (3.35)
Three countries excluding China				
Cognitive Development	-1.150 (1.72)	-2.690 (2.21)	0.877 (1.73)	0.959 (1.89)
Language & Emergent Literacy	-0.676 (1.68)	0.091 (1.48)	0.674 (1.44)	1.893 (1.62)
Socio-emotional Development	-2.550 (1.40)	-2.527 (1.67)	-3.259 (2.28)	0.185 (2.25)

* $p < .05$. EAP-ECDS scores are country and age-adjusted z-scores re-centered at mean 100, standard deviation 15 points.

Supplementary Table 10

Estimated association of ECE duration (months) and EAP-ECDS scores by duration category, compared to under 7 months (all four countries combined, and three countries excluding China)

	7 to 18 months	**19 to 30 months**	**31 or more months**
	β (SE)	*β (SE)*	*β (SE)*
All four countries combined			
Cognitive Development	-0.476 (0.93)	0.860 (1.50)	4.092* (1.34)
Language & Emergent Literacy	0.602 (0.77)	2.407* (0.59)	1.550 (2.04)
Socio-emotional Development	-0.802 (0.58)	0.269 (1.08)	2.009 (1.31)
Three countries excluding China			
Cognitive Development	-2.105 (1.23)	-2.61 (1.68)	1.557 (2.04)
Language & Emergent Literacy	0.453 (1.22)	2.032 (1.37)	5.603* (1.95)
Socio-emotional Development	-1.629 (1.08)	-3.586* (1.21)	0.043 (1.50)

* $p < .05$. EAP-ECDS scores are country and age-adjusted z-scores re-centered at mean 100, standard deviation 15 points.

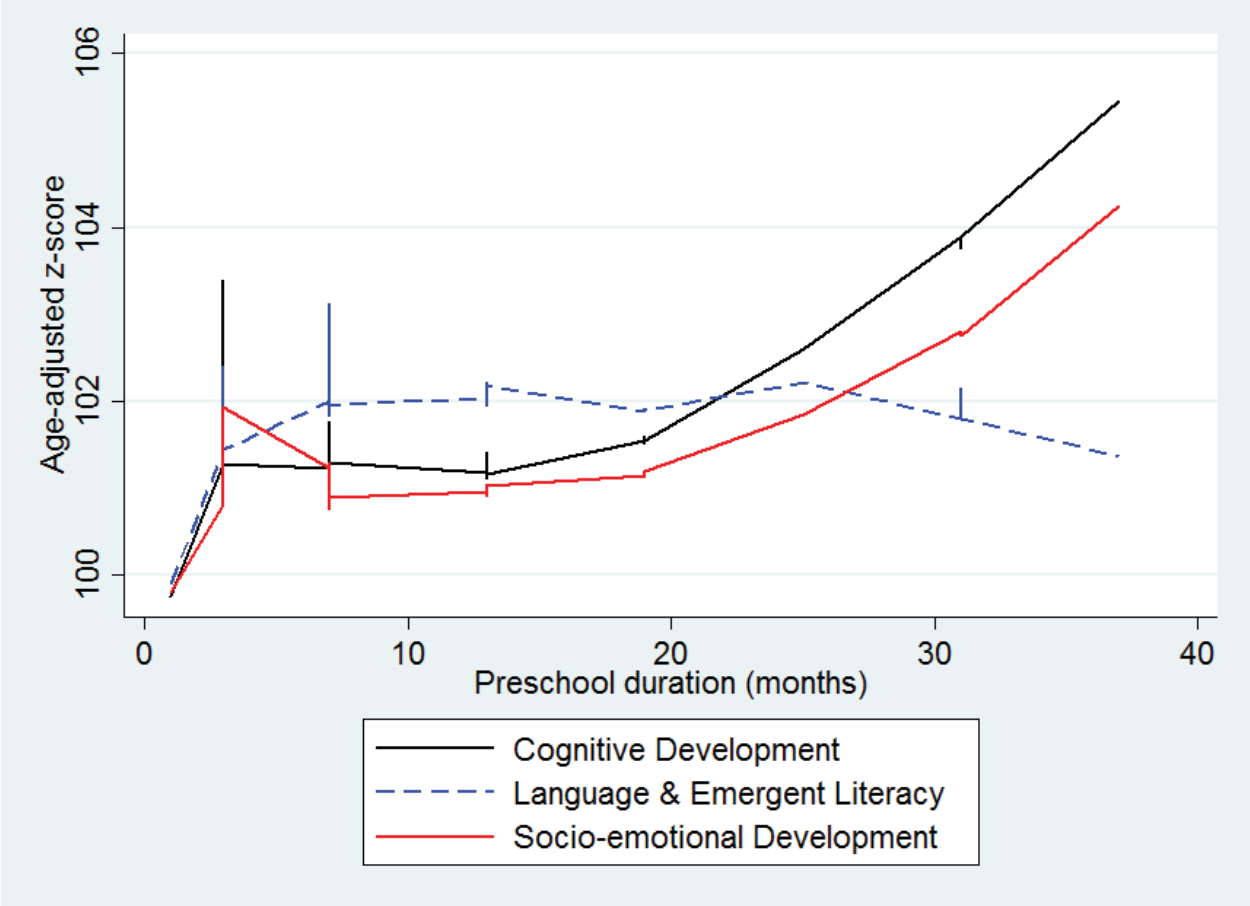
Supplementary Table 11

Proportion of total variance at level 2 for each regression model reported in Tables 3 and 4 and in Figure 2

	All 4 countries	3 countries excluding China	Cambodia	China	Mongolia	Vanuatu
Participation (Table 3)						
Cognitive Development		6.8%	0.2%		2.3%	14.4%
Language & Emergent Literacy		8.6%	9.1%		5.9%	7.5%
Socio-emotional Development		9.5%	3.2%		15.7%	10.3%
Dosage (continuous, Table 4)						
Cognitive Development	18.5%	10.6%	3.9%	3.8%	4.4%	17.9%
Language & Emergent Literacy	12.2%	8.8%	6.5%	5.2%	3.2%	6.9%
Socio-emotional Development	8.5%	7.3%	0.0%	2.4%	14.6%	7.5%
Dosage (categorical, Figure 2)						
Cognitive Development				3.8%	4.6%	
Language & Emergent Literacy				5.2%	3.2%	
Socio-emotional Development				2.5%	14.6%	

Supplementary Figure 1

Change in age-adjusted domain-specific z-scores by ECE duration (months) across three domains (all four countries combined)



Note: Supplementary Figure 1 shows descriptive statistics of age-adjusted country-specific domain z-scores for children with different experiences of preschool duration (in months). A running mean procedure was applied to the data.