**Let's Talk about Maths:**

**The Role of Observed 'Maths-Talk' and Maths Provisions in Pre-schoolers' Numeracy.**

**Running Head: Preschool Practitioners' Maths Talk**

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**Acknowledgements.** This project was supported by the Nuffield Foundation. We would like to thank our advisory team more broadly for their support with the project. We are especially grateful to Keely Cook, Jane Maharry and Joanne Mason for their invaluable help with recruitment of Oxford-based Early Years settings. Special thanks also to Freya Prentice, Rebecca Ashworth, Ruxandra Vasile and Xanthippi Alexi Vassiliou for help with data collection during the study.

Finally, we are especially appreciative of the time, energy and enthusiasm given by the wonderful preschool practitioners, children and parents who participated in the project and were so accommodating of our efforts to research the preschool learning environment.

**This examination of educational aspects to preschool maths was conducted as part of a larger study funded by the Nuffield Foundation: 'The Cognitive and Educational Foundations of Preschool Maths: not as easy as 1, 2, 3.' (link)**

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## Abstract

Developmental cognitive neuroscience highlights the importance of interactions between children and their environment. As young children spend increasing time in childcare, it is key to investigate the impact of ‘maths talk’ and maths provisions in preschools. Qualitative insights from early educators indicate a greater bias towards counting activities than would be expected given the early years curriculum. In addition, we quantified the observed breadth of preschool practitioners’ maths language (e.g., place-value language), setting-based maths provisions (e.g., quality of maths-related activities), and their relation with children’s early numeracy skills. In settings with greater practitioners’ breadth of maths language, children display greater cardinality skills although our data call for the further investigation of parental SES and education. We conclude with a discussion on the need to operationalise children’s maths learning environments as diversely as possible. Enriching practitioners’ skill sets may be an effective and needed way of improving early maths outcomes.

**Running Title:** Pre-school Maths-Talk and Maths Provisions

**Key words**

Child, Preschool

Mathematics

Language

Learning

Teacher Training

# Let's Talk about Maths:
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Existing cognitive, educational and developmental research has identified significant individual differences in maths-related ability by the age of 4 (Dowker, 2005; 2008). These differences predict later academic outcomes (Duncan et al., 2007). This has prompted considerable interest in and discussion of the possible influence of children's environment in the early years on their general cognitive abilities and more specific skills such as early maths performance.

Research from disciplines such as neuroscience, biology and economics has also highlighted a need to understand children's early environment, given its influence on the development of children's neural architecture and function (Knudsen, Heckman, Cameron, & Shonkoff, 2006), through dynamic interactions between genes, brain, cognition and environment (Karmiloff-Smith, 2009). From a biological perspective (Sokolowski & Ansari, 2018), in the early years the environment may play an even stronger role in mediating a child's individual genetic pre-dispositions for maths or more general cognitive abilities than later. This is because young children have relatively little control over the environment in which they are placed compared to later in development, when there is more opportunity for children to select learning environments or opportunities that align with their particular strengths. Together, multiple disciplines, from education to neuroscience, highlight a need to investigate how aspects of children's early learning environment may influence mathematical development in particular.

## How does the Early Educational Environment affect Maths Development?

The term ‘Early Environment’ can be conceptualised in different ways and could refer to a range of variables such as learning provisions and opportunities as well as linguistic input and exposure to adult-led teaching. In the context of the home learning environment, previous research has commonly used measures of parent language use and activity engagement, parental education level and Socio-Economic Status (SES), as relevant indicators (LeFevre, Skwarchuk, Smith-Chant, Fast, Kamawar, & Bisanz, 2009; Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010). Indeed, considerable individual differences in maths abilities, evident by the age of 4, are related to socio-economic status (Jordan, Huttenlocher, & Levine, 1992; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006; Starkey, Klein, & Wakeley, 2004). Crucially, these discrepancies have been associated with differences in maths-related parent input and interaction with children at home (e.g., Blevins-Knabe & Musun-Miller, 1996; DeFlorio & Beliakoff, 2015). Much of the existing research investigating the relation between child-directed maths language and early maths understanding has been conducted specifically within the home learning environment, studying the quality and quantity of mathematical input from parent to child. For example parental focus on quantities beyond four items (Gunderson & Levine, 2011), as well as parental beliefs about their own math self-efficacy and beliefs about their role in children’s math learning (Davis-Kean & Sexton, 2009; Elliott & Bachman, 2018; Vasilyeva, Laski, Veraksa, Weber & Bukhalenkova, 2018) have been found to predict young children’s math outcomes. Levine and colleagues (2010) found a huge range in frequency of parent number talk observed during daily activities in the home and, crucially, found a significant positive correlation between the amount of parent number talk and children’s cardinality understanding by the age of 46 months. However subsequent research only found this significant positive relation between parent maths talk and children’s maths abilities when parent language used numbers larger than 10 (Elliott, Braham, & Libertus, 2017). Less well understood is the role played by the volume, quality, and breadth of maths language used by early educators, as well as available maths provisions in Preschool (see Appendix 2 – Glossary), to which we now turn.

**Early Educational Settings: Educator Maths Language and Maths Provisions**

Klibanoff and colleagues (2006) showed that the amount of maths talk used by teachers in preschools and day-care centres (Chicago, US) was significantly related to the growth of preschoolers' maths knowledge over 4 months (in 4- to 5-year-olds). They observed a wide variation in the amount of maths talk used by teachers and, crucially, that a larger amount of maths talk was associated with greater diversity of the types of maths language used. In order to investigate diversity of types of maths talk, mathematically relevant language input was coded into categories of input type. They found that language around Cardinality accounted for the largest amount (48%) of maths utterances with other types of input like Ordering (sequences) and Placeholding (place value: decomposition of large numbers into smaller units like tens and ones) contributing only 4% and 1% respectively. More recent research in Dutch kindergarten classrooms in early elementary schools (with 5-year-olds) shows that teachers' Cardinality talk and use of numbers for ages, dates, and times is positively related to children's number skills, but does suggest some interesting inverse relations with other types of maths talk such as Calculation (Boonen, Kolkman, & Kroesbergen, 2011). Taken together, this literature suggests that teacher maths language use relates particularly to children's number skills, but that investigations may vary considerably depending on whether the measure of 'maths talk' involved considers different types of maths language or simply indicates the volume of total utterances related broadly to maths.

In addition to maths language directed by individual Early Years practitioners (see Appendix 2), it is also important to consider the influence of maths provisions at a preschool setting level. With limited funding being a common problem across many educational institutions, it is highly relevant to consider the effect of available physical resources and how they are utilised in high quality educational provision. The Early Childhood Environment Rating Scale-Extended Edition (ECERS-E) is a means of assessing the 'process quality' of early educational environments across key academic areas (Sylva et al., 2006). This measure of quality relates to process elements like the nature of activities and learning opportunities available to the children and that of adult-child interactions (Sylva, Siraj-Blatchford, & Taggart, 2010; See Appendix 2 for further details). This differs to measures of structural quality, which considers the adult-child ratio of the setting groups or level of teacher education and training. The Maths-subscale of the ECERS-E, hereby referred to as ECM (Early Childhood – Maths), offers a way to evaluate educational aspects of maths provisions such as visual displays, physical resources, and evidence of relevant activities put on within a learning environment that pertain specifically to foundational maths areas. To avoid confusion in terminology, following recommendations by two anonymous reviewers, we shall refer to the process quality indexed by the ECM with the term "Maths Provisions" henceforth, to make it clear that ECM transcends physical or visual resources alone. Longitudinal research in German preschools has indicated that the process quality of the preschool (as measured by complete ECERS-E score), although not related to numeracy skills at preschool entry, is significantly related to development of numeracy skills across the years of preschool attended from 3 to 5 years of age (Anders et al., 2012).

**The present study**

Here we aimed to offer insight into the variability of maths-related practitioner language use and maths-related provisions across preschool settings, as well as highlighting the experience of Early Years educators in delivering preschool maths.

In study 1 we investigated the types of maths language used by practitioners across various daily activities and share the qualitative findings from interviews with Early Years educators. Study 2 offered a quantitative approach to assessing the relation between differing measures of preschool environment (practitioners' maths talk and maths provisions) and several key preschool maths skills (e.g. cardinality, verbal counting, and symbolic number knowledge). We hypothesised that our indicators of preschool environment such as breadth of practitioners' maths language would be positively associated with better early maths outcomes, as measured by higher performance scores in assessments of cardinality, counting, and number naming.

## Study 1: Qualitative Insights from Practitioners' Interviews

### Method

This examination of educational aspects to preschool maths was conducted as part of a larger study funded by the Nuffield Foundation: 'The Cognitive and Educational Foundations of Preschool Maths: not as easy as 1, 2, 3.' (link)

#### Participants

Thirteen Oxfordshire preschool settings were recruited into the study. One setting was excluded as they withdrew before completion of data collection and classroom observations ($N$=12; *SES Median (IMD Decile;* see Appendix 2 - Glossary*)* = 8; see Table 1).

Across settings, 67 key workers (KW; see Appendix 2) were recruited to the study and $N$ = 51 (76%) (see Table 1) were interviewed (100% female). The further 16 practitioners were unable to participate in the interviews due to absence on interview days, personal commitments, or their setting withdrawing from the study. The number of key workers and children they supervise varied across different preschool settings (see Table 1 for available structural data at the setting level).

Informed consent was gained from the preschool settings' manager and from individual KWs. To ensure confidentiality, data was anonymised using setting identification numbers.

---- Table 1 approximately here ----

**Procedure**

Semi-structured interviews called 'Lunch and Learn' were held in the settings (see Appendix 1 for the list of questions that were used in each interview, and principal areas of discussion). Two Research Assistants (RAs) conducted interviews, one facilitating the discussion and one taking detailed notes, complemented with any additional observations immediately after concluding each interview session. Because of the absence of a second note-taker, unfortunately inter-rater reliability could not be calculated for Study 1. The interview sessions lasted between 30 and 60 minutes; depending on the number of attendees and length of answers. To make the sessions accessible to the practitioners, 'Lunch and Learn' took place at a time best suited to the setting and most of its staff. To allow for staff to be released from preschool commitments without interfering with their working patterns, practitioners were interviewed in a group or individually, as appropriate.

Additionally, settings were observed by two RAs during the Summer term, before "Lunch and Learn" interview sessions at each setting, to prevent the semi-structured interviews in Study 1 from unduly influencing the natural course of observed activities and maths language in each setting. During the observation, practitioners were asked to deliver a normal day activity. Researchers observed for around 15 minutes at a given time period, or until to the activity ended (*Mean* observation time = 14.33 minutes, *Range* = 8-24 minutes).

Observations were carried out in all settings of a: circle time; snack or lunch; and child-led activity. In 75% of settings ($N = 9$), an adult-led activity was also observed, but this was not universal practice across settings. 45 activity sessions were observed in total across the 12 settings (see Table 1), with one practitioner typically observed in each observation. If possible, a different practitioner was observed for each activity. Although practitioners were informed about the types of sessions observed, and the methods of observation, they were blind to the focus on maths language.

To retain anonymity of non-volunteering individuals, ethically approved protocols precluded the use of audio or video recording equipment for the observations. Therefore, both RAs recorded in free form the practitioner's use of maths-related language and subsequently coded these notes using NVivo software in each of the 6 categories devised by Libertus and Braham (2016), as *observed vs. not observed*. On "presence" of a type of maths language, agreement was 100%. This coding method, the variable length of observations across activities and settings, and the absence of a measure of general language used (which could only have been derived from verbatim transcription of all language used), meant that it was not possible to compute a frequency index for each type of maths language.

**Data Analysis**

Following data collection, the records of 'Lunch and Learn' and observations were anonymised in relation to the setting and practitioners. Thematic analysis was then used to identify the main themes of the observations and interviews as outlined by Braun, Clarke, and Terry (2014). Inductive coding was used for 'Lunch and Learn' (see Table 2) whereas deductive coding of the maths language observed was employed using the maths language categories established by Libertus and Braham (2016) (see Table 3). As much extraneous maths related language was found after coding, a miscellaneous maths code was established.

This included concepts such as comparative language (e.g. 'bigger') and shape (e.g. 'triangle').

---- Tables 2 and 3 approximately here ----

## Results

### Maths Language Use

Observations of the range of maths language used by preschool practitioners showed that across the 45 activity sessions the majority included maths language surrounding cardinality, whereas maths language surrounding place value was less well represented. (See Table 4 for proportions of observed activities containing instances of each maths talk category, Table 5 for proportions of settings in which instances of language from each maths category were observed in the different activity sessions, and Table 6 for observed maths language examples). Furthermore, 89% of activity sessions included some form of observed miscellaneous mathematical language use by practitioners (see Table 7 for observed miscellaneous maths language examples).

---- Tables 4, 5, 6 and 7 approximately here ----

### Best Practice Maths Activities

Practitioners provided a range of activities when asked what activities they feel work well in their settings (see Table 2). The settings gave examples of activities which related to counting and cardinality (91.67%); units of measure (83.33%); and ordering and number recognition (83.33%). Seventy-five percent of settings also offered illustrations of practice which related to shape. On the other hand, only 16.67% of settings provided examples of activities which related to calculation, and no settings offered suggestions for good practice associated with place value.

### Broadening the Maths Curriculum

Practitioners reflected on the breadth of the maths curriculum which they felt they provided, and would like to provide, to children in preschool. A bias towards counting activities was identified by several KWs who are *'…mainly focusing on counting and wonder if could focus more on other maths areas'* and *'could do more weighing as predominantly counting focused'.* Settings reflected on their own progress in providing a broad mathematics curriculum, such as:

*'initially it was difficult to know what aspect of maths … but as went on got better understanding of different maths areas'* and *'we were using different language, like smaller and bigger. I wouldn't have done that previously'.*

**Maths Confidence**

When discussing maths confidence, two areas began to emerge: the practitioner's confidence in teaching maths in preschool and their own confidence in maths. Statements such as *'I can do the basics; counting, simple sums'* shows that practitioners feel confident in their maths subject knowledge within the context of preschool. On the other hand, they did not feel fully confident with mathematics beyond the preschool curriculum. One KWs viewpoint that they *'wouldn't have a clue in a school'* highlights the practitioner's concerns regarding their own understanding and skills with mathematical concepts.

**Training**

Many practitioners mentioned the lack of specific training for maths within both their qualifications and continuing professional development ("CPD"). They stated that they *'haven't had specific maths training'* and several practitioners expanded on this point saying that they would *'like more specific training'*. They were keen for this training to include a breadth of maths curriculum:

*'a lot of people focus on counting but there doesn't seem to be enough training on how to incorporate the other areas like volume and positioning'.*

**Interim Discussion**

Observations and interviews with practitioners paint a picture of preschool maths pedagogy which focuses on counting and cardinality. Although data was not collected regarding the frequency or volume of maths language, instances of counting and cardinality language were observed across the majority of settings and observed activities, more so than the other maths talk categories. This bias was identified by practitioners in their interviews and witnessed in the common use of maths language in these areas, as well as the majority of settings offering suggestions for good practice activities linked to counting and cardinality. At the other end of the spectrum, the preschool settings observed here offered children very little experience of place value and lack of examples of these activities within their settings.

It is important to note that practitioners also reflected on their practice related to areas such as the Early Years Foundation Stage (EYFS, See Appendix 2) ‘shape, space, and measure’ area of learning. Although practitioners gave examples of activities for various maths categories, data were not collected on how frequently these activities are done in practice. Ideas of best practice and consideration of how they covered these areas of the curriculum were seen in the ‘Lunch and Learn’ findings and also the large amount of maths data we observed but were unable to code into the existing themes. It would appear that in this study there was a mismatch between the maths specifically and the real life application of practitioners. A proportion of the additional categories fall under the umbrella term of spatial talk, and these categories (studied extensively by Cannon et al., 2007) should therefore be investigated further.

Furthermore, the findings of the practitioner interviews suggest that the KWs feel confident to deliver the curriculum related to counting and calculation at the preschool-level; however their confidence did not extend to the maths education of older age groups. Still, many practitioners stated how they would like to receive further training on specific maths pedagogy suited for preschool. Given the lack of EYFS maths training and the disparity between how the different areas of maths were discussed and observed within the settings, it may be pertinent to consider how preschool maths related professional development can be supported.

## Study 2: Observed Maths Language Breadth, Maths Provisions and Early Numerical Skills

### Methods

#### Participants

Two-hundred and thirty-two children took part in the study. 24 participants were excluded because data was missing on at least one of the number tasks (15), because of withdrawal of their setting (8) or because of transfer to a different setting (1). Of the remaining 208 children, 102 were girls ($M_{age}$ = 45.75 months, Range = 35-55, *SD* = 4.43). The following demographics were calculated through parental report: Socio Economic Status (SES, Index of Multiple Deprivation Decile based on nationally available postcode indices of deprivation in the United Kingdom; English Index of Multiple Deprivation 2015 - Guidance), Parental Education Level (Simmons et al., 2017, education level of parent / guardian responding). Demographics are reported in Table 8, see Appendix 2 – Glossary for more details.

---- Table 8 approximately here ----

#### Materials

***Environmental Measures***

**Observed Practitioner Maths Language Breadth (OML)**: At each setting described in Study 1, instances of maths language use were across 3 observed activities (circle time, snack time, child-led free flow play) by two RAs. A cumulative variable indexing maths language breadth observed was created by categorising each of six types of maths language in an activity (as defined by Libertus and Braham, 2016) as either *observed* or *not observed*.

**ECERS-E, Mathematics sub-scale (ECM)** (Sylva et al., 2006): The Mathematics subscale of the Early Childhood Environment Rating Scale – Extended Edition (ECERS-E) was used to generate a score of maths provisions per setting. This was achieved through observations of maths-related teaching and activities by key workers, even embedded within 'not-specifically-maths-related' activities such as snack time, as well as evidence of physical resources available and in use to support maths learning, as guided by the ECERS-E scoring manual and specific instructions within the Mathematics Scoring Sub-section. (Sylva et al., 2010; See Appendix 2 for further administration details).

### *Children's Numerical Skills Assessments*

**Give N Task**. This is an established test of cardinal number knowledge (Wynn 1990; 1992). Data were collected on children's ability to give the experimenter a set number of items from a larger group of tokens. Traditionally this task focuses on numbers 1-5 but we also included numbers up to 8, to tap individual differences in our target age range. Our cardinal number knowledge score indicated the highest number of items the child was able to give without making an error. (See Appendix 2 – Glossary for further administration details)

**Counting High Task.** This is used to assess counting ability. Children were asked to count as high as they can. Our counting score indicated the highest number reached without error in sequence.

**Number Naming Task.** This is a digit identification task taken from the Numeracy Screener (Nosworthy, Bugden, Archibald, Evans, & Ansari, 2013), focused on children's symbolic number knowledge. Children are asked to name numbers 1-9 twice on a page, in nonsequential order. The total number of correctly named digits (out of 18) is used as a 'digit identification' measure for analysis.

**Procedure**

Instances of maths-specific language were observed as described in Study 1 and then categorised into one of 6 categories ('Calculation, Cardinality, Counting, Ordering, Place Value, and Units of Measure', following, Libertus & Braham 2016, See Table 3). Quantitative analysis only includes data from the 3 activities consistently observed across all settings (Circle time, snack/meal time and free-flow play). While at each setting, an environmental assessment was carried out using the Mathematics subscale of the ECERS-E (Sylva et al., 2010). The three numeracy tasks (Give N, Counting High and Number Naming) were administered one-to-one by a researcher with individual children in a quiet area of the nursery classroom, or a separate room if available at the setting. Numeracy tasks were administered within a larger battery of assessments for a wider study. Order of administration of the number tasks was counterbalanced across children.

**Analysis**

Settings were clustered into a 'High Maths Focus' and 'Low Maths Focus' group, first according to Observed Maths Language Breadth (OML) and second based on ECERS-E maths subscale (ECM) rating. OML and ECM were scored and analysed as two separate factors. This is due to the small number of settings, uneven group sizes and IMD Decile stratification across each cell constituting the four combinations of OML and ECM. These data limitations precluded a full factorial and parametric ANOVA / ANCOVA approach. OML Breadth scores use the same observed practitioner data from study 1, excluding data from the 4$^{th}$ observed (adult-led) activity since this was only observed in 9 of the 12 settings. In order to obtain consistent scores across settings, observational data was included only from the 3 activities observed across all 12 settings. OML: Settings that scored 10 or above out of a possible 18 for Observed Maths Language Breadth were assigned to the 'High' Group (N=6). Settings that scored 9 or below were allocated to the 'Low' Group (N=6). ECM: Settings that were rated as 'excellent' or 'good' according to the ECM scoring categories were assigned to the 'High' Group (N=5). Settings that had ECERS-E Maths scores rated as 'minimal' or 'inadequate' were assigned to the 'Low' Group (N=7). Table 8 shows demographic information for children in the High and Low maths focus settings, according to Observed Maths Language or ECERS-E Maths Scale Rating criteria. Not all parent questionnaires were returned, but all available information was used and Ns reported accordingly. Although parental SES and education were not environmental targets of interest in this study, in Table 8 we note parental differences across High and Low maths focus settings.

The assumption of normality was not met for any of the three number tasks (Give N, Count High and Number Naming, $p_s < .05$). Consequently, non-parametric Mann-Whitney tests were used to compare mean differences in performance on each task between Low and High settings, for both OML and ECM criteria.

**Results**

As expected, the overall sample of preschoolers varied widely in terms of performance on each of our target numeracy tasks. For Give N, the average cardinality score was 4.64 (SD = 2.435, range 1-8). For Count High, the average highest number counted correctly was 15.72 (SD = 11.746, range 0-100). For Number Naming, the average was 11.12 (SD = 6.570, range = 0-18).

Performance was significantly higher in High OML settings (Mdn = 5) than in Low OML settings (Mdn = 3) on the Give N task, $U = 4237.5$, $p = .007$. Counting high scores were numerically also higher in High OML settings (Mdn = 14) than in Low OML settings

(Mdn =13), although this difference did not reach statistical significance, $U = 4839.0$, $p = .256$. Similarly Number Naming scores were higher in settings of High OML (Mdn = 14) compared to Low OML (Mdn = 12), but this did not reach statistical significance, $U = 4732.0$, $p = .129$.

When comparing settings of High and Low ECM, results indicated that, surprisingly, overall performance was significantly higher in Low ECM than in High ECM settings. Give N scores were significantly higher in Low ECM settings (Mdn = 5) than in High ECM settings (Mdn = 3), $U = 3608.0$, $p < .001$. On the Counting high task, performance was significantly higher in Low ECM (Mdn = 14) compared to High ECM (Mdn = 12) settings, $U = 4325.5$, $p = .028$. Similarly, Number Naming scores were significantly higher in Low ECM (Mdn = 15) than High ECM (Mdn = 11) settings, $U = 4129.0$, $p = .007$. Although we were concerned that these differences may depend on underlying parental SES differences, we were not adequately placed to study the effects of SES in these analyses because SES was not stratified across groups, and clustered at the higher end, (see Table 8). It would not have been statistically appropriate to treat parental SES as a continuous covariate. We carried out an exploratory ANCOVA with parental SES as a covariate and the ECM group differences were no longer statistically significant, but we note caution, given that data distributions did not warrant the use of parametric statistics.

# General Discussion

## Main Findings and Implications

The aim of Study 2 was to extend practitioners' insight on maths-relevant preschool activities and training, to investigate the influence of Maths language and Maths Provisions on multiple foundational maths skills. We had hypothesised better maths skills for children in high versus low Maths focus settings. Results from Study 2 showed that cardinality understanding, counting ability and number naming were higher in ‘High OML’ compared to ‘Low OML’ settings, this difference was statistically significant only for cardinality understanding. Furthermore, contradicting expectations, children in High ECM settings performed significantly lower on all early maths tasks compared to children in Low ECM settings.

Children’s performance on the Give N task, as an index of cardinality knower level (Wynn, 1990; 1992) was higher in High OML settings (Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Klibanoff et al., 2006). This is consistent with existing literature: for example, Hornburg, Schmitt, & Purpura (2018) investigated the relation between preschoolers’ maths language and a range of specific numerical skills like verbal counting and numeral identification. They found a significant relation between maths language and most numeracy abilities, including the two aforementioned skills and cardinality, but not with subitizing or formal addition skills. Prior work also suggests higher maths skills in preschool children attending settings with more varied observed maths language than those from ‘lower’ (i.e. less varied) maths language settings (Klibanoff et al., 2006). In our sample of UK-based preschool children, cardinality understanding was strongly related to the breadth of maths language exposure and interactions with key workers, whereas the effects of OML were weaker, and did not reach significance, for counting and number identification. It is possible that these skills are more influenced by frequency or *volume* of maths language rather than by *breadth* of maths language. Indeed, instances of counting were observed across the vast majority of settings and activities. Data collected in the present study are not able to address the question of frequency or volume of maths language, only breadth. Previous research suggested that children are very familiar with counting language (e.g. through preschool, parents and educational television programs, Boonen et al., 2011), so the breadth of maths language might be less important for counting skills compared to cardinality understanding, due to the large volume of counting language already available in a child’s environment. Future studies should also look to investigate when instances of counting and cardinality language are distinct as opposed to overlapping or used together, as these language categories are often relevant to the same activity which may facilitate reinforced learning across the two skills and areas of language.

Interestingly and contrary to our expectations, preschoolers from settings with lower ECERS-E maths subscale ratings performed significantly better across all three maths tasks than those attending ‘High ECM’ settings. Our preliminary analyses suggest that this difference may mask effects of parental education level and parental SES in the two settings, as “Low ECM” settings also displayed the highest parental education and SES. Since our study was not optimised to test parental variables, further analyses and a larger, stratified sample would be needed to investigate these findings. Indeed, a large scale longitudinal study employing the ECERS-E subscales across a large sample of preschool settings also showed the surprisingly absent relation between preschools’ maths subscale (ECM) scores and children’s maths skills (Sylva, Melhuish, Sammons, Siraj-Blatchford, & Taggart, 2008), whereas other ECERS-E subscales related to maths outcomes. Although administering assessments beyond the ECERS-E maths sub-scale was beyond the scope of the current project, these similar unexpected findings further highlight the importance for diverse environmental measures, as supposedly domain-specific measures of provision do not relate as might be expected.

Policy makers are increasingly recognising the importance of the early environment and provision for children’s broad development (Sylva & Pugh, 2005; Taggart et al., 2015; Taguma, Litjens, & Makowiecki, 2012). Recent statistics show 96% of 4 year olds in the UK access some form of government funded childcare or early education (*Childcare and Early Years Survey of Parents in England*, 2017). Our varying findings across environmental measures in Study 2 demonstrate that it is especially relevant to identify informative and varied measures of maths-related adult input, maths provisions and learning opportunities within this preschool environment, beyond the home learning environment. We identified a bias towards areas like counting, as well as under-represented mathematical areas like place value in preschool maths talk. These findings relate strongly to the feedback received from preschool practitioners about early maths provision as well as teacher training in Study 1. This is important to highlight, since the Early Years Foundation Stage (EYFS) includes a range of areas within early maths learning, such as 'Shape, Space and Measure', that should be covered by the start of school. However, in practice, coverage of the wider foundational maths areas, in both Early Years pedagogy and educator training opportunities, appears to be significantly less common than would typically be inferred from the EYFS.

Indeed, Study 1 shows that we should particularly focus efforts on improving early educational policy in this area. Policy-makers are arguably well-placed to inform early educators of the importance of diverse maths language and facilitate better training across a varied early curricula for foundational maths beyond counting. Crucially, based on the feedback and qualitative findings from Study 1, this would likely be welcomed by Early Years practitioners themselves.

**Limitations**

Some important methodological limitations are worth foregrounding. First, two research assistants conducted semi-structured interviews, pragmatically arranged either in groups or with individual practitioners, with one RA facilitating the discussion and one taking detailed notes, complemented with any additional observations immediately after concluding each interview session, but the absence of an additional note-taker precluded computing inter-rater reliability scores for Study 1. Second, two RAs also observed each example of classroom activity, but our Research Ethics approved protocol did not allow us to video- or audio-record either interviews or observations. This recording method had an impact on coding options for our index of Maths-Talk: by necessity, we adopted a classification method based on the presence or absence of a particular type of maths-language. This was pragmatically necessary, because an index of relative frequency of maths-specific use (e.g., compared to general language use, or as a proportional score) could not be obtained reliably under the current recording conditions and with variable observation length. Our Maths-Language score, therefore, was very conservative, as it did not discriminate between settings for which a certain type of maths language was present, but infrequent, and settings in which instead this maths language was much more frequent. Future studies should complement breadth and frequency measures. Third, we focused Study 2 on maths-specific language, rather than including additional miscellaneous language, such as spatial language, emerging from qualitative work in Study 1. We note that there is extensive work on spatial language (e.g., Cannon, Levine, & Huttenlocher, 2007), whereas maths-specific research was scarce when we started. Demographic information at a practitioner level such as age and years of teaching experience was not collected. We encourage future research to consider these variables in further investigations of practitioner maths language use.

With regards to the distinction between diversity and quantity of maths-talk, much of the previous studies into maths language investigate relations between the volume or frequency of maths talk spoken by a parent or teacher and the child's maths vocabulary. However, research suggests that the diversity and sophistication of adult vocabulary input is more important than quantity when children are at least 3 years of age, before which quantity may play a greater role (Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991). Thus, in relation to early maths development, broad, diverse and sophisticated adult maths language may facilitate children's early mathematical understanding. Our focus on breadth, although not indicative of quality or quantity per se, does illustrate diversity of input.

It is important to note that, although they were unaware of particular hypotheses relating to the effect of practitioner maths language use on preschoolers' maths, practitioners knew that this project was investigating early maths. Therefore, they were not blind to our mathematical focus so may have been primed to use more maths language while being observed than they would otherwise. However, despite this knowledge, we still saw a great disparity in maths language categories observed across activities and settings. This suggests that although practitioners may have been aware of our interest in 'maths' they varied in how they incorporated wider maths language such as place value into their activities, as compared to more common cardinality language.

**Future Directions**

Future studies with a larger sample of settings should investigate effects at both the setting and individual practitioner level. Previous research has shown that higher teacher confidence in mathematics is associated with higher perceived importance of maths in the classroom, more maths learning opportunities, and more use of developmentally appropriate methods of teaching maths (Geist, 2015). Similarly, teachers who believed maths instruction should be a primary goal of preschool education talked more about Cardinality, Ordering, and Units of Measurement (Libertus & Braham, 2016). This suggests that teachers' personal beliefs influence how frequently they teach these foundational number concepts and that teachers who are more comfortable with higher level maths concepts may be more inclined to teach these more advanced skills. Therefore future research should aim to recruit a larger range of settings in order to compare individual and setting level effects on maths language use as this may further highlight the importance of teacher training opportunities in maths available to individual practitioners rather than setting managers for example.

The diverse effects of maths language breadth and maths educational provisions require further investigation with a study that also quantifies possible interactions with parental education and SES. In other words, thinking about a child's "environment" as unitary is far too simplistic, even in the preschool years. Equally, diverse effects across number skills highlight how environments impact certain cognitive outcomes more than others (Sokolowski & Ansari, 2018), perhaps because of different interactions between children's readiness to learn and the variable role of quantity or breadth of exposure. In turn, these complexities highlight that an understanding of early maths learning requires studying both children's neurocognitive skills and the diverse ways in which environmental variables support them.

**References**

Anders, Y., Rossbach, H.-G., Weinert, S., Ebert, S., Kuger, S., Lehrl, S., & von Maurice, J. (2012). Home and preschool learning environments and their relations to the development of early numeracy skills. *Early Childhood Research Quarterly*, *27*(2), 231–244. https://doi.org/10.1016/J.ECRESQ.2011.08.003

Blevins-Knabe, B., & Musun-Miller, L. (1996). Number Use at Home by Children and Their Parents and Its Relationship to Early Mathematical Performance. *Early Development and Parenting*, *5*(1), 35–45. https://doi.org/10.1002/(SICI)1099-0917(199603)5:1<35::AID-EDP113>3.0.CO;2-0

Boonen, A. J. H., Kolkman, M. E., & Kroesbergen, E. H. (2011). The relation between teachers' math talk and the acquisition of number sense within kindergarten classrooms. *Journal of School Psychology*, *49*(3), 281–299. https://doi.org/10.1016/j.jsp.2011.03.002

*Childcare and Early Years Survey of Parents in England*. (2017). Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/669857/SFR73_2017_Text.pdf

Davis-Kean, P. E., & Sexton, H. R. (2009). Race differences in parental influences on child achievement: Multiple pathways to success. Merrill-Palmer Quarterly (1982-), 285-318.

DeFlorio, L., & Beliakoff, A. (2015). Socioeconomic status and preschoolers' mathematical knowledge: The contribution of home activities and parent beliefs. *Early Education and Development*, *26*(3), 319-341.

Dowker, A. (2005). Early Identification and Intervention for Students With Mathematics Difficulties. *Journal of Learning Disabilities*, *38*(4), 324–332. https://doi.org/10.1177/00222194050380040801

Dowker, A. (2008). Individual differences in numerical abilities in preschoolers. *Developmental Science*, *11*(5), 650–654. https://doi.org/10.1111/j.1467-

7687.2008.00713.x

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., … Japel, C. (2007). School readiness and later achievement. *Developmental Psychology*, *43*(6), 1428–1446. https://doi.org/10.1037/0012-1649.43.6.1428

*The English Index of Multiple Deprivation (IMD).* 2015 – Guidance (department for communities and local government). Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/464430/English_Index_of_Multiple_Deprivation_2015_-_Guidance.pdf

Elliott, L., Braham, E. J., & Libertus, M. E. (2017). Understanding sources of individual variability in parents' number talk with young children. *Journal of Experimental Child Psychology*, *159*, 1–15. https://doi.org/10.1016/j.jecp.2017.01.011

Elliott, L., & Bachman, H. J. (2018). SES disparities in early math abilities: The contributions of parents' math cognitions, practices to support math, and math talk. *Developmental Review, 49*, 1-15.

Geist, E. (2015). Math Anxiety and the "Math Gap": How Attitudes toward Mathematics Disadvantages Students as Early as Preschool. *Education*, *135*(3), 328.

Gunderson, E. A., & Levine, S. C. (2011). Some types of parent number talk count more than others: relations between parents' input and children's cardinal-number knowledge. *Developmental Science*, *14*(5), 1021–1032. https://doi.org/10.1111/j.1467-7687.2011.01050.x

Hornburg, C. B., Schmitt, S. A., & Purpura, D. J. (2018). Relations between preschoolers' mathematical language understanding and specific numeracy skills. *Journal of Experimental Child Psychology*, *176*, 84–100. https://doi.org/10.1016/J.JECP.2018.07.005

Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., & Lyons, T. (1991). Early vocabulary growth: Relation to language input and gender. *Developmental Psychology*, *27*(2), 236–248. https://doi.org/10.1037/0012-1649.27.2.236

Jordan, N. C., Huttenlocher, J., & Levine, S. C. (1992). Differential calculation abilities in young children from middle-and low-income families. *Developmental Psychology, 28*(4), 644-653.

Karmiloff-Smith, A. (2009). Nativism versus neuroconstructivism: Rethinking the study of developmental disorders. *Developmental Psychology*, *45*(1), 56–63. https://doi.org/10.1037/a0014506

Klibanoff, R. S., Levine, S. C., Huttenlocher, J., Vasilyeva, M., & Hedges, L. V. (2006). Preschool children's mathematical knowledge: The effect of teacher "math talk"; *Developmental Psychology*, *42*(1), 59–69. https://doi.org/10.1037/0012-1649.42.1.59

Knudsen, E. I., Heckman, J. J., Cameron, J. L., & Shonkoff, J. P. (2006). Economic, neurobiological, and behavioral perspectives on building America's future workforce. *Proceedings of the National Academy of Sciences of the United States of America*, *103*(27), 10155–10162. https://doi.org/10.1073/pnas.0600888103

LeFevre, J.-A., Skwarchuk, S.-L., Smith-Chant, B. L., Fast, L., Kamawar, D., & Bisanz, J. (2009). Home numeracy experiences and children's math performance in the early school years. *Canadian Journal of Behavioural Science/Revue Canadienne Des Sciences Du Comportement*, *41*(2), 55–66. https://doi.org/10.1037/a0014532

Levine, S. C., Suriyakham, L. W., Rowe, M. L., Huttenlocher, J., & Gunderson, E. A. (2010). What counts in the development of young children's number knowledge? *Developmental Psychology*, *46*(5), 1309–1319. https://doi.org/10.1037/a0019671

Libertus, M. and Braham, E. (2016, September). *Maths Talk Variabilities in preschool classrooms: The role of teachers' abilities and beliefs.* Poster presented at the International Mind Brain and Education Conference, Toronto, CA

Nosworthy, N., Bugden, S., Archibald, L., Evans, B., & Ansari, D. (2013). A Two-Minute Paper-and-Pencil Test of Symbolic and Nonsymbolic Numerical Magnitude Processing Explains Variability in Primary School Children's Arithmetic Competence. *PLoS ONE*, *8*(7), e67918. https://doi.org/10.1371/journal.pone.0067918

Simmons, F.R., Willis, C., & Adams, A-M. (in preparation). Examining the influence of the home learning environment, language and cognitive abilities on children's early number skills. Project website, consulted 19.11.2018.

Sokolowski, H. M., & Ansari, D. (2018). Understanding the effects of education through the lens of biology. *Npj Science of Learning*, *3*(1), 17. https://doi.org/10.1038/s41539-018-0032-y

Starkey, P., Klein, A., & Wakeley, A. (2004). Enhancing young children's mathematical knowledge through a pre-kindergarten mathematics intervention. *Early Childhood Research Quarterly*, *19*(1), 99-120.

Sylva, K., Siraj-Blatchford, I., Taggart, B., Sammons, P., Melhuish, E., Elliot, K., & Totsika, V. (2006). Capturing quality in early childhood through environmental rating scales. *Early Childhood Research Quarterly*, *21*(1), 76–92. https://doi.org/10.1016/J.ECRESQ.2006.01.003

Sylva, K., Siraj-Blatchford, I., Taggart, B., (3rd Revised Edition, 2010) *ECERS-E: The Early Childhood Environment Rating Scale Curricular Extension to ECERS-R.* Stoke-on-Trent: Institute of Education Press

Sylva, K., Melhuish, E., Sammons, P., Siraj-Blatchford, I., & Taggart, B. (2008) Effective Pre-school and Primary Education 3-11 Project (EPPE 3-11) Final report from the primary phase: Pre-school, school and family Influences on children's development during Key Stage 2 (age 7-11). Nottingham: *Department of Children, Schools and Families Publications.*

Taggart, B., Sylva, K., Melhuish, E., Sammons, P., & Siraj, I., (2015) Effective Pre-school and Primary Education 3-11 Project (EPPE 3-16+) Research brief: How pre-school influences children and young people's attainment and developmental outcomes over time. *Department for Education.*

Taguma, M., Litjens, I., & Makowiecki, K. (2012). *Quality Matters in Early Childhood Education and Care: Finland*. OECD Publishing. 2, rue Andre Pascal, F-75775 Paris Cedex 16, France.

Vasilyeva, M., Laski, E., Veraksa, A., Weber, L., & Bukhalenkova, D. (2018). Distinct Pathways From Parental Beliefs and Practices to Children's Numeric Skills. *Journal of Cognition and Development*, *19*(4), 345-366.

Wynn, K. (1990). Children's understanding of counting. *Cognition*, *36*(2), 155–193. https://doi.org/10.1016/0010-0277(90)90003-3

Wynn, K. (1992). Children's acquisition of the number words and the counting system. Cognitive Psychology, 24(2), 220–251. https://doi.org/10.1016/0010-0285(92)90008-P

## Tables

**Table 1:** Setting and Participation Information per Preschool Setting

| Setting ID | Type: (Work Place Nursery; Charity Preschool; School Nursery) | Location: (Rural; Urban | Ratio of Staff to Children (Adult: Child)* | Number of preschool practitioners interviewed in 'Lunch & Learn' | Practitioners interviewed in groups or individually | Number of activities observed |
|---|---|---|---|---|---|---|
| 101 | Charity Preschool | Rural | 1:6 | 6 | Group | 3 |
| 103 | School Nursery | Urban | 1:10 | 7 | Group | 4 |
| 104 | Charity Preschool | Urban | 1:5 | 13 | Group | 4 |
| 105 | School Nursery | Urban | 1:7 | 3 | Group | 4 |
| 106 | Charity Preschool | Rural | 1:4 | 1 | Individually | 3 |
| 107 | School Nursery | Urban | 1:9 | 4 | Group | 4 |
| 108 | Charity Preschool | Rural | 1:4 | 4 | Individually | 4 |
| 109 | Charity Preschool | Rural | | 3 | Individually | 4 |
| 110 | Work Place Nursery | Urban | 1:8 | 4 | Individually | 4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 111 | Work Place Nursery | Urban | | 3 | Individually | 4 |
| 112 | Work Place Nursery | Urban | | 1 | Individually | 3 |
| 113 | Work Place Nursery | Urban | | 2 | Individually | 4 |
| TOTAL | 4 Work Place Nurseries<br>5 Charity Preschools<br>3 School Nurseries | 4 Rural<br>8 Urban | * | 51 | 5 Group<br>7 Individually | 3 settings had 3 activities observed<br>9 settings had 4 activities observed |

*Note: Setting 102 withdrew from the study prior to observations and data collection.*

** Structural data i.e. Adult:Child ratios are missing for 4 of the 12 settings.*

*Work place nursery: A nursery business which provides year round care for children;*

*Charity Preschool: An independently run preschool or nursery which is not directly under the management of a school but runs as a charity organisation. Typically these run in term-time only;*

*School Nursery: A nursery class(es) managed by a primary, infant or a foundation-stage school.*

*Rural: defined as an area with a population below 10,000 in 'Defining Rural Areas' (DEFRA)*

**Table 2:** Codes generated for 'Lunch and Learn' by thematic analysis

| Theme | Code | Definition | Example |
|---|---|---|---|
| Broadening the maths curriculum | Challenges of assessment | Difficulties practitioners noticed in establishing what children know in maths. | "I think we are meeting needs but sometimes with number like adding etc. it's tricky to tell amongst a big group to focus on one thing and one child." |
| | Range of maths curriculum | The various aspects of maths curriculum covered in practitioners' provision. | "A lot of people focus on counting etc. but there doesn't seem to be enough training on how to incorporate the other areas like volume, positioning." |
| | Embedded maths curriculum | Building maths learning into other areas of the curriculum and daily routines. | "Snack times we do counting name tags etc." |
| | Maths Language use | The use of maths-related language with the preschool children. | "We try to use maths vocabulary everywhere." |
| Maths confidence | Maths confidence teaching EY | The practitioners' feelings of confidence related to teaching early years maths. | "I feel confident. In here, children are young enough, they only need to be able to count to 10." |

| | | | |
|---|---|---|---|
| | General maths confidence | The practitioners' feelings of confidence related to teaching maths outside of the Early Years or using maths in their daily lives. | (I can do the basics, counting, simple sums etc. because they're quite young it's ok but) "wouldn't have a clue in a school." |
| Training | Training courses | The practitioners' views on the training they have received, and would like to receive, related specifically to maths. | "Need training available for Early Years maths and how to implement it in settings, and much more beyond just number counting or recognition. " |
| Best practice maths activities | Calculation | Activities suggested by EY practitioners that relate to addition, subtraction, division or multiplication. | "building with clicking cubes, take two away etc." |
| | Cardinality and counting | Activities suggested by EY practitioners that relate to counting items or actions, identifying how many or linking a number name to an amount. | "Counting cups during snack time" |

| | | | |
|---|---|---|---|
| | Ordering and number recognition | Activities suggested by EY practitioners that relate to assigning meaning to Arabic numerals and ordering numbers into a sequence. | “Car park with numbers in spaces and put number stickers on car and kids had to match number on car with parking space.” |
| | Units of measure | Activities suggested by EY practitioners that relate to measuring. | “Sand and water play” |
| | Shape | Activities suggested by EY practitioners that relate to shapes. | “shape hunt” |
| | Other | Activities suggested by EY practitioners that relate to areas of maths not defined by the categories above. | “using beebots for direction” |

*Note. ‘EY’ stands for Early Years which covers the period from birth to 5 years of age (and in this context the preschool year of children aged 3-4 in particular).*

**Table 3:** Maths Number Language categories of Libertus and Braham (2016)

| Maths Number Language Category | Definition |
|---|---|
| Calculation | Performing an operation or asking the child to solve a calculation problem. |
| Cardinality | Starting or asking for the number of items in a set without counting them. |
| Counting | Reciting count words, counting objects in a set or asking children to count. |
| Ordering | Instances that refer to a sequence. |
| Place Value | Decomposing a number. |
| Units of Measure | The use of numbers as labels for ages, dates or time. |

*Note: Libertus & Braham (2016) offer maths language categories condensed from those seen in previous studies such as those by Kilbanoff et al. (2006); Levine et al., (2010).*

**Table 4:** Proportion of the total 45 observed activities across 12 settings containing language from each Maths Talk category

| Maths Talk Category | Proportion of activities observed containing language from each Maths Talk category (%) |
|---|---|
| Cardinality | 82 |
| Counting | 73 |
| Ordering | 60 |
| Calculation | 49 |
| Units of Measure | 47 |
| Place Value | 2 |
| Miscellaneous | 89 |

*Note: Percentages given to nearest whole number. Proportions out of 12 participating settings*

**Table 5:** Proportion of Settings using Language from each Maths Category per Activity Session

| | Proportion of Settings (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Counting** | **Cardinality** | **Ordering** | **Calculation** | **Place Value** | **Units of Measure** | **Miscellaneous** |
| **Carpet Time** | **92** | **83** | **75** | **50** | **8** | **67** | **83** |
| **Free Flow Play** | **67** | **83** | **42** | **50** | **0** | **33** | **100** |
| **Snack Time** | **67** | **92** | **67** | **58** | **0** | **58** | **92** |

*Note: Percentages given to nearest whole number. Proportions out of 12 participating settings*

**Table 6:** Maths Language observations from qualitative Study 1

| **Area of Number** | **Examples of language used** |
|---|---|
| Calculation | "What is <u>the difference</u> if Z. had two and D. had three?"<br>"Five <u>add</u> five is?"<br>"Six and <u>one more</u> makes seven"<br>"If I <u>take one</u> cup <u>away</u>, how many are left?" |
| Cardinality | "Show me seven fingers."<br>"Six cups and six plates"<br>"Where's four spots?"<br>Singing rhymes e.g. Five little ducks |
| Counting | "Count with us together"<br>"How many cups?"<br>"Let's count the name tags, one at a time, 1-2-3-4-5-6"<br>Singing rhymes including recitation of count words e.g. "1, 2, 3, 4, 5, once I caught a fish alive" |
| Ordering | "What's after four?"<br>"If yesterday was the 7th, today is? The 8th"<br>"First sit down, then eat"<br>"1-2-3 what's coming next?"<br>"After Monday then..?" |
| Place Value | "11 is 10 children and one more" |
| Units of Measure | "Four years old"<br>"The date is the 8th"<br>"One minute sand timer" |

| | |
|---|---|
| | "One litre" |

**Table 7:** Miscellaneous Maths Language observations from qualitative study 1

| Area of maths | Description | Example of language observed |
|---|---|---|
| **Amounts** | Non-numerical description of quantity. | "Some more"<br>"A lot of"<br>"Pair of shoes"<br>"All of them" |
| **Comparative Language** | Language to describe the comparison of two or more amounts or objects. | "Which one is smaller?"<br>"A bigger wall"<br>"tower is higher"<br>"Is that the same?" |
| **Language of measurement** | Non-numerical descriptions of size. | "long"<br>"heavy"<br>"big"<br>"little" |
| **Number recognition** | Identifying Arabic numerals and mapping to their corresponding numerical values. | "I can see that is 1 and zero …10"<br>"Where's number nine?"<br>"Is this 24?"<br>"If you put it like this it's number 6, if you put it like this it's number 9." |
| **Positional Language** | Where something is located. | "On the top"<br>"next to"<br>"up" |

| | | |
|---|---|---|
| | | "down" |
| **Shape** | 2D and 3D shape names and descriptions of their properties. | "What is this shape?"<br>"straight"<br>"Curved"<br>2D and 3D shape names |

**Table 8:** Child sample demographics split by High and Low Maths focus Settings in Study 2

| | *N* | Observed Maths Language (OML) Rating | | ECERS-E Maths Scale (ECM) Rating | |
|---|---|---|---|---|---|
| | | High | Low | High | Low |
| SETTINGS | 12* | 6 | 6 | 5 | 7 |
| CHILDREN | 208** | 111 | 97 | 87 | 121 |
| Age (months) (rounded) | $M = 46$ (Range = 35-55) | $M = 46$ (Range = 35-54) | $M = 46$ (Range = 37-55) | $M = 45$ (Range = 36-54) | $M = 47$ (Range = 35-55) |
| SES (IMD Decile) *** | $M = 7.5$ (Range = 2-10) $N = 170$ | $M = 7.89$ (Range = 2-10) $N = 104$ | $M = 6.88$ (Range = 3-10) $N = 66$ | $M = 6.73$ (Range = 3-10) $N = 70$ | $M = 8.04$ (Range = 2-10) $N = 100$ |
| Parent/Primary Care Giver Education *** (Score, 1-8) | $M = 5.86$ (Range = 2-8) $N = 159$ | $M = 6.24$ (Range = 2-8) $N = 97$ | $M = 5.26$ (Range = 2-8) $N = 62$ | $M = 5.31$ (Range = 2-8) $N = 62$ | $M = 6.21$ (Range = 2-8) $N = 97$ |

*Note. * Out of 13 Settings originally recruited (1 setting withdrew prior to observations).*
*** Out of 231 children recruited in original cross-sectional sample.*
****Please note that parental SES and education were not target environmental variables here (See Appendix 2 – Glossary). However, we report a comparison between parental variables in "Low OML" versus "High OML" settings (Parental SES: "Low OML" smaller than "High OML", $U = 2605.50$, $p = .007$, Parental Education: "Low OML" smaller than "High OML", $U = 2208.00$, $p = .004$) and in "Low ECM" and "High ECM" settings (Parental SES: "Low ECM" greater than "High ECM", $U = 2295.50$, $p < .001$, Parental Education: "Low ECM" greater than "High ECM", $U = 2335.50$, $p = .014$).*

## Appendices

**Appendix 1 - <u>'Lunch and Learn' interview</u>**

*Note: These interviews were semi-structured. Questions were asked in the same order in all interviews. All questions were asked unless an answer to the question had already been given by a member of the group or the individual practitioner during discussion of previous questions. Follow-up questions depended on the response of the practitioner(s) being interviewed.*

**Principal areas for discussion:**

Tell me about the professional development you have received. Have you ever had specific maths professional development? What qualifications do you have?

How confident do you feel with maths related activities?

What do you feel supports you to teach maths in your preschool?

Tell me about how you plan for the needs of individual children in your setting? Do you use assessment and observation? How?

What do you think about the children's progress in maths?

Do you have any maths activities which you would recommend to other practitioners? What activities works well/are best practice?

Would you like to tell me anything else about your experiences in teaching maths?

**Appendix 2 – Glossary**

*The Early Childhood Environment Rating Scale – Extended Edition (ECERS-E):*

The ECERS-E is an observational scale that was conducted by two researchers so that raters could reach an agreement for a score when scores were discrepant. It offers additional notes and clarifications to ensure those conducting the evaluation score consistently with what the indicators are intended to assess. Scoring notes clearly guide administrators to assign specific ratings based on the number of indicators scored as YES or NO i.e. Observed or not observed (e.g. 'rating of 5 is given when all indicators under 5 are scored YES'). The majority of evidence should come from observed activities and behaviours. Additionally, the tool offers clear guidance on where to look for supplementary evidence if observation is not possible, e.g. items with a 'Q' indicate 'evidence from questioning acceptable' or 'D': 'evidence from displays/photographic records acceptable'. It also includes optional items in order to make it possible to evaluate what is most evident on the day of observation. This makes it more manageable for settings since it would be unrealistic to expect to observe all relevant behaviours and activities in one sitting that encapsulate the complex pedagogical interactions the ECERS-E aims to assess. For example within the maths sub-scale: the 'mathematical activity' item could be one of either 'sorting, matching, and comparing'; or 'shape'.

For more information, see ECERS-E: The Early Childhood Environment Rating Scale Curricular Extension to ECERS-R by Kathy Sylva, Iram Siraj-Blatchford and Brenda Taggart (third edition, published 2010).

*Early Learning Goals (ELGs):* establish the expected outcomes for children by the end of the EYFS in each area of learning. The maths-related ELGs relate to Numbers and Shape, Space, and Measure.

*Numbers:* children count reliably with numbers from 1 to 20, place them in order and say which number is one more or one less than a given number. Using quantities and objects, they add and subtract two single-digit numbers and count on or back to find the answer. They solve problems, including doubling, halving and sharing.

*Shape, Space, and Measure:* children use everyday language to talk about size, weight, capacity, position, distance, time and money to compare quantities and objects and to solve problems. They recognise, create and describe patterns. They explore characteristics of everyday objects and shapes and use mathematical language to describe them.

*Early Years Foundation Stage:*

The early years foundation stage (EYFS) sets standards for the learning, development and care of children from birth to 5 years old. All schools and Ofsted-registered early years providers must follow the EYFS, including childminders, preschools, nurseries and school reception classes. The EYFS only applies to schools and early years providers in England. There are different early years standards in Scotland and Wales.

The EYFS is also referred to as a period of time e.g. 0-5 years but to avoid confusion, ‘preschool’ is used throughout this article for this context, specifically referring to 3 and 4 year olds. This period has a statutory outcome (*Early Learning Goals*, see above) like the key stages have SATs or GCSE's.

*Early Years Practitioner:*

A person who has studied, or gained qualifications, to and work with children from birth to 5 years old.

*Give N Task:*

This is an established test of cardinal number knowledge (Wynn 1992), even though it varies in exact administration. Data were collected on participants' ability to give the experimenter a set number of items from a larger group. In this study children were asked to 'feed Mr Monkey' (a puppet) X bananas from a bowl of 15 bananas, placing the requested number on a plate in front of the puppet. Traditional reporting on the task focuses on numbers 1-5 but we also included numbers to 8. If participating children make an error, i.e. give Mr Monkey the wrong number of bananas, the experimenter asks for the previous number and then works back up again following a correct trial. Testing stops either when the child correctly presents all numbers asked for or when they've made two errors on the same number. The cardinality measure (dependent variable) was the highest number the participant reached without making any errors on any attempts.

*The Index of Multiple Deprivation Decile (IMD Decile):*

The Index of Multiple Deprivation (2015) is the official measure of relative deprivation for small areas (or neighbourhoods) in England. It is common to describe how relatively deprived a small area is by saying whether it falls among the most deprived 10 per cent, 20 per cent or 30 per cent of small areas in England (although there is no definitive cut-off at which an area is described as 'deprived'). Deciles are calculated by ranking the 32,844 small areas in England from most deprived to least deprived and dividing them into 10 equal groups. These range from the most deprived 10 per cent of small areas nationally to the least deprived 10 per cent of small areas nationally. IMD Decile of 1 indicates the most deprived decile and a decile of 10 indicates the least deprived/most affluent decile. For the present study, the site http://imd-by-postcode.opendatacommunities.org/ was used to input participant post codes to generate a measure of socio-economic status, in particular the Index of Multiple

Deprivation Decile. For more information, see The English Index of Multiple Deprivation (IMD) 2015 – Guidance (Department for Communities and Local Government).

*Key Worker:*

Key workers (sometimes referred to as key adults) are Early Years practitioners who support a specific group of children within a setting. Their role is to provide support for the child's individual needs and build a relationship with the child and their family.

*Parental Education:*

Parents were asked to complete a parent questionnaire (Simmons et al. in prep) including a question asking "What is the highest degree or level of school you have completed?" This education information of the respondent was taken to be that of the primary care giver (137 female, 22 male) and used as the index of 'Parental Education'. An education level score between 1 and 8 was assigned based on parent's responses to this parent questionnaire item. The lowest score of 1 indexed a parent's highest level of schooling as the equivalent to e.g. GCSE at grades D-G, NVQ Level 1, or Key Skills Level 1. A parent education level score of 2 was equivalent to e.g. GCSE at grades A*-C, NVQ Level 2, or Key Skills Level 2. A score of 3 was equivalent to e.g. AS and A level, NVQ Level 3, or Key Skills Level 3. A score of 4 was equivalent to e.g. Certificate of higher education, NVQ Level 4, or Key Skills Level 4. A score of 5 was equivalent to e.g. Diploma of higher education or Foundation degree. A score of 6 was equivalent to e.g. Graduate certificate/diploma or Bachelor's degree. A score of 7 was equivalent to e.g. Postgraduate certificate/diploma or Master's degree. The highest possible score of 8 indexed highest education level as the equivalent of NVQ Level 5 or Doctorate.

*Preschool:*

For the purposes of this study, using a UK-based sample, ‘preschool’ refers to children aged between 3 and 4 years old. Preschool settings included are those offering early education and child care for this age range in preparation for the start of formal schooling at the age of 5. The settings included work place nurseries, independently run charity preschools, and school based nurseries (see Table 1).