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ORIGINAL ARTICLE

Fostering young children's interest in numeracy through demonstration of its value: the Footsteps Study

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Abstract Children's early mathematical abilities are fundamental to their later academic achievement. An interest in mathematics in the early years is likely to establish a positive attitude to later mathematical learning, hopefully sustaining continued interest in mathematics and mathematical learning. Approaches to early mathematics teaching in the early years, however, are typically adult-initiated, which may fail to capture children's interest. Given the importance of children's motivation and sustained interest, the study described here strove to spark children's interests in mathematical problems in everyday life. The study sought to determine if children would incorporate more numeracy-related concepts into their free play if exposed to adult demonstrations of age-appropriate numeracy activities such as patterning. For at least 15 min three times weekly, participating children's parents and educators demonstrated numeracy problem-solving nearby, while children engaged in other activities. Demonstrations were thought to ascribe social value to the problem-solving activities. If children became interested in participating, adults told them to wait until the demonstrations finished, further indicating social value. Results show these children chose to play with numeracy-related activities in their free play time at preschool significantly more than children in a control group. These results suggest that seeking to foster children's interest in mathematics through child-initiated play, rather than prescribing adult-initiated mathematics activities, may be an important means of laying the foundation for lifelong mathematics learning. Ascribing social value to numeracy applications is proposed as a new approach to teaching mathematics in the early years.

Keywords Play-based curricula · Learning through play · Legitimate peripheral participation · Child-initiated mathematics

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Introduction

The first 5 years of life are being increasingly identified as crucial for sustained health, academic achievement and overall quality of life (Curenton et al. 2015; Moffitt and Caspi 2001; Shonkoff et al. 2009). Investment in these years has been shown to yield the greatest returns for society (Heckman and Masterov 2007), in the vicinity of 16 times any cost (Schweinhart et al. 2005). One plausible explanation for this high impact lies in the amount that children learn and develop during the early years.

Early cognitive ability has been shown to predict general academic achievement later in life (Pearce et al. 2016). Specifically, early mathematical ability is one of the best predictors of later achievement (Huntsinger et al. 2000; Jordan et al. 2007; LeFevre et al. 2009). For example, it may even predict reading skills better than general literacy itself (Duncan et al. 2007). As such, programs that target mathematical ability may be the most effective in maximising early learning (National Research Council 2009) not only for mathematical skills but for academic achievement overall. Thus, many programs seek to maximise mathematics learning during this period, either as resources used in addition to curricula (e.g. *Count Me In Too* in Australia; Meiers et al. 2013) or as whole curricula that are run instead of play-based ones (e.g. *HeadStart* in the USA; Marcon 2002).

However, there is a range of reasons why targeted mathematics programs may be unsuitable for young children (Press and Hayes 2000). For instance, increased pressures to perform academically early in life have significant impacts on children's mental and emotional well-being (Elkind 2007; Ginsburg 2007). While programs targeting mathematical skills may seem most direct and effective, their forced nature risks instilling in children a dislike of mathematics (and school) that will have lasting impacts on their motivation to learn throughout life (Doig et al. 2003). Learning studies (e.g. Habgood and Ainsworth 2011) show that intrinsically motivated activities (in which children are driven by their enjoyment of the task) result in greater engagement and better learning outcomes than those in which an adult offers rewards for those tasks. Thus, it is important that activities are enjoyable and create enduring positive emotional associations for children. Yet, this is a formidable task for programs based on adult-initiated activities (Hunting et al. 2012; Wager 2013).

In a large cohort of over 4000 children, Carmichael et al. (2014) show that children's mathematical abilities are at least 0.17 standard deviations higher if they like mathematics than if they do not. Analyses of multiple studies verify that attitudes towards mathematics have a significant effect on mathematics achievement (Casey et al. 2016; Ma and Kishor 1997). Some 25 studies have shown that children's interest in a topic has strong effects on academic achievement in that area (Schiefele et al. 1992).

Interestingly, Carmichael et al. (2014) found that while parental involvement in school had a positive impact on grades, parental help with homework actually had a negative one. Their findings suggest that parents may hinder overall achievement when they enforce adult-initiated activities that children are unlikely to want to do (i.e. homework, which is often done while more attractive leisure activities compete for the child's interest).

Another problem with adult-initiated programs is that even initially engaging programs may not remain interesting for long enough for children to build numeracy skills (Marcon 2002; Meiers et al. 2013). One way to circumvent this problem is to focus on sustaining children's interest in the application of mathematics. The study described here sought instead to examine if adults' demonstrated use of numeracy would impact child-initiated activities (i.e. free play), without prompting children to engage in any adult-guided activities. It is assumed that children initiating and guiding their own mathematical inquiry is much more likely to engage their motivation and sustain their long-term interest than are adult-guided interventions.

Many studies also show that achievement improves when children feel like they are driving their learning (Hattie 2008) and drops when parents expect more than what children are capable of (Murayama et al. 2016). This over-expectation problematic is also avoided when children initiate and guide their own learning, fuelled by an interest in the topic. Fostering an enjoyment of mathematics and letting the child initiate the learning is likely to be more effective than prescribing that learning.

One way to spark children's interest is using practical applications of a range of mathematical skills rather than a limited range. Implementing interventions that guide mathematical activities *exclusively* may detract from the desired holism of early learning (OECD 2006; Wager 2013). As a result, many early mathematics interventions (e.g. Clements and Sarama 2008; Ginsburg 2002) have made the learning of abstract constructs more practical by contextualising them within everyday life (e.g. setting the dining table).

Conclusive longitudinal data now supports the above ideas, showing that early childhood programs that yield the best long-term academic results are those that include child- as well as adult-initiated activities (Sylva et al. 2014). Many adult-directed interventions for literacy, for example, are more effective when balanced with child-initiated activities (Chambers et al. 2016; Han et al. 2010). When compared to academically focussed early programs, curricula that are predominantly child-initiated (i.e. play-based) yield significantly better outcomes by sixth grade (Marcon 2002) and less criminal tendencies in adulthood (Schweinhart and Weikart 1997). Such findings imply that programs should include as many child-initiated experiences as possible, given their tendency to be designed and therefore directed by adults, not children. A survey of the literature reveals no numeracy programs to date have focussed on child-initiated activities as the basis for learning. This sits in contrast to the dominant approach in the field of early childhood education (ECE).

The problem with the dominant ECE approach

Within Western heritage contexts (e.g. Western Europe, Australasia etc.), ECE is based on the principle that children's development occurs naturally. Just as children's bodies grow, so do their cognitive, emotional, social and emotional aspects (Copple and Bredekamp 2009). Learning is internally driven as the child strives to understand the world, and the goal of the educator is to assist rather than prescribe this learning (Wood 2013). The child's interests are considered an indication of that natural process and should be supported by the adult (Gibbons 2007; Nutbrown et al. 2008; Stephen 2012). In the early years, free play is considered the dominant driver of development and learning (Karpov 2005), as well as an indication of what the child is interested in and should learn about (Hedges and Cooper 2016). Children's interests and dispositions towards learning are considered far more important than academic achievement itself

(Gibbons 2007; Hedges and Cullen 2012). This approach to early education is widely considered to be the most effective in the early years (Copple and Bredekamp 2009; OECD 2006; Stephen 2012).

Yet, this approach to ECE can be problematic. To understand one reason why, it is helpful to distinguish between what Rogoff and colleagues' call 'traditional' and 'industrialised' societies (Gutierrez and Rogoff 2003; Rogoff et al. 2006). In traditional societies, caregivers must contribute to subsistence work practices (e.g. hunting, cultivating or preparing foods) while also caring for children. As a result, children are exposed to these practices from a young age and usually participate in them; first by observing but then increasingly through hands-on experience (Lave and Wenger 1991). As children strive to understand their world, they observe what they see around them and imitate and practice what they see in their free play (e.g. playing mothers and babies, hunting, cooking etc.; Elkonin 2005). As they observe and imitate over the years, they learn the skills they require to fully participate in work (Rogoff et al. 2006). The learning described in traditional societies is largely synonymous with the type of learning upheld in the dominant ECE approach. It reflects the notion that children observe, play with and learn about practical skills they will need to for later life. As children are exposed to work practices, they represent these practices in their play, and learn about them, learning practical skills and concepts through their play.

Work in industrialised (and post-industrialised) societies, on the other hand, is thought to require a set of more complicated and abstract skills (e.g., reading, writing, mathematical calculations, interpretation of data etc.). To acquire these skills, children must engage in abstract learning activities in institutions that are separated from the home and workplace (e.g. ECE settings, schools, etc.; Rogoff et al. 2006). This configuration greatly limits opportunities for learning about work practices through observation. Further, what needs to be learned is not determined through participation (as in traditional societies). Instead, expert adults must determine what children need to learn. Learning must be adult-initiated because the content must be determined by adults.

Mathematics is one example. It is often taught as abstract skills (e.g. algebra, calculus) that will lead to the thinking required for learning more practical skills (e.g. computer programming, financial services, construction). However, as discussed earlier, when adults prescribe what children should learn, it can reduce motivation and limit holistic learning. There is a conflict, then, between the learning we want children in (post-) industrialised societies to accomplish and the accepted approach to learning mathematics. The conflict is heightened by modernisation in post-industrialised societies in which children are exposed to, observe and play with ideas from the mass media and commercial companies. Rather than being exposed only to the daily practical activities of their parents, as in traditional societies, children are now almost constantly exposed to television, the Internet, advertising and commercial products as well (Norberg-Hodge 2000). This configuration complicates the observation-participation-learning process because much of what children observe and play with is not directly useful in, or relevant to, the acquisition of practical skills for later life (e.g. learning about Spiderman™ is unlikely to have much use later in life).

Educators in post-industrialised societies widely report the conflict between what children observe, play with and are interested in—on the one hand—and what adults want them to learn (i.e. curriculum content)—on the other (Anning 2010; Cooney

2004; Rogers and Evans 2008). Linking child-initiated play with curriculum content is usually a very difficult task (Hedges and Cooper 2016; Wood 2007). While various suggestions have been made as to what makes it difficult (e.g. Adams et al. 2004; Fleer et al. 2009), there has been little interrogation of the fact that observation- and participation-based learning is likely to have evolved in *Homo sapiens* in learning configurations similar to traditional societies and *dissimilar* to industrialised societies. The intervention described here sought to utilise these natural learning processes in mathematics by sparking children's interest in practical mathematical problems. Because learning through observation and experimentation is child-initiated, and is shown to be more effective than adult-initiated learning, this study strived to find a way to make mathematics learning child-initiated. The most obvious way to do so appeared to be through sparking children's interest in mathematics. Although the intervention sought to influence both numeracy and literacy abilities, this paper will focus on the numeracy component to illustrate how content that is traditionally learned through adult-initiated activities may be learned in child-initiated and practical ways.

Making early mathematical knowledge applicable to daily life

Games are often used to incorporate mathematical content into an intrinsically motivated learning activity (although extrinsic motivators like rewards and congratulations are common in video games). However, unless there are opportunities for extensive conversations between players about mathematical operations (as is possible in multiplayer board games, for example), the mathematical content to be learned is often quite limited. For example, the popular app Candy Crush Saga™ is usually played solo and challenges players to develop their use of *one* operation (matching like with like) in *one* context (a two-dimensional grid), limiting the depth of conversation topics generated. Further, the challenges that keep mathematical games interesting are rarely about the practical application of mathematics, which often requires adaptive and evolving learning. In most cases, although the games result in some mathematics learning, these games are merely incentivising the acquisition of one or two operations rather than fostering children's interest in mathematics per se, which would be child-initiated learning.

However, practical applications of mathematical operations using everyday objects are more likely to have much more tenure in children's everyday life. Practical applications are thus more likely to be of interest, sustaining children's learning and engagement. Moreover, if children are exposed to practical applications of mathematical operations and thinking (see Table 1), then daily life is likely to present a variety of problems and ideas that they can become interested in and solve. Due to the variety of applications available, they are able to progress to more complex problems to solve, as their skills and understandings develop. In this way, it seems more important that children become interested in mathematics than that they acquire specific content knowledge or operational skills (Wager 2013).

By demonstrating mathematics applied to daily life, this study enables children to observe the way the operations are undertaken and emulate that in their play. Recent scholarship on early mathematics has moved away from a focus solely on the rather abstract concept of numbers and towards practically applied relationships and

Table 1 Numeracy and literacy skills used in demonstrations

Academic content	Daily problem	Skills demonstrated to solve problem	Scripts excerpts	Practical applications	Materials provided
Numeracy	Making patterns	Counting, deduction, addition, multiplication	Adult A: Okay, first let's start with the fork, then place a plate next. Can you put the knife after the plate? Adult B: Yep, so how do we repeat this as a pattern now?	Setting the table, counting bricks in a wall, colouring bricks/fence posts in patterns, drawing patterned borders, blocks, hopping and jumping, placing shells and stones along an edge of carpet	Paper, chalk, brick walls, plates, cutlery, coloured blocks, crayons, shells, stones
	Deciphering patterns	Counting, deduction, subtraction, division	Adult A: I think we need to divide six by the number of blocks in the unit of repeat. So that's one purple and one orange. One, two. So if we want to divide the six bricks in the wall by two, we'd get that three times. Is that right?		
Literacy	Writing letter to family member	Who to address letter to, what message can be communicated	I want to write a letter to Grandma to say hello and 'I love you'. I think she'd like to get a letter from me. I might draw her a picture	Sending a letter to a relative, reading signs at restaurants, playing games with letters or words, spelling people's names	Easel, paper, crayons, chalk board, chalk
		What sounds each letter makes in words	I want to write 'to Grandma'. I want to start with the word 'to' and want a letter that makes the sound /t/ /t/ /t/. Which letter makes the sound /t/?		
		Sending letter by post	I'm going to fold the letter in half, like this, then again, and put it in an envelope. What do we need to write on the envelope for the mail carrier?		Envelope, stamp, pen
	Spelling simple words	Select letter cards to change existing word into another (e.g. hat→cat)	What letter can I change to make a new word? What about if I change the letter aitch to another letter? I'm going to put the letter cee. Now the word says /k/ and /ae/ and /t/. Hmmm…cat?		Letter card

transformations (Ginsburg 2002; Papic and Mulligan 2005; Warren 2005). Instead of focussing on abstractions such as concepts of multiplication and subtraction, there is a growing body of work focussing on the application of these relationships in patterns (Fox 2006; Papic et al. 2015; Warren 2005). For example, a coloured block tower may repeat a simple pattern of red, red and blue (RRB) multiple times to interrogate questions of multiplication or division. These explorations may prompt and answer questions such as: How many red blocks are there in a RRB–RRB pattern? How many in one unit of repeat? How many units of repeat in a RRB–RRB–RRB tower? (See Appendix 1 for how these types of questions were explored in dialogues in the intervention.) Answers to these sorts of questions provide the basis for understanding, for example, the multiplication of three and five as a binary operation. Other examples of contexts in which patterns find practical application to daily life include hopping and jumping sequences, colouring bricks with chalk, drawing borders and setting the dining table with cutlery (see Table 1). While patterning is often explored using specialist materials, one of its benefits is its practical applicability to a range of contexts and materials commonly found in everyday life. This transferability is important if an intervention is to be conducted in homes as well as ECE centres. The importance of this transferability is discussed below.

Family partnerships

The intervention described here sought to involve prominent family members, who are the subject of children's imitation in traditional (Rogoff et al. 1993) and post-industrial societies (Colliver 2016). In post-industrial societies, young children's lives are increasingly fragmented by the separation of care, education, entertainment and home contexts. As young children move from the home to an ECE (or school) setting on a daily basis, they must reconcile differences between settings. Recent longitudinal research shows just how important continuity between settings is (Melhuish 2010). For example, literacy and numeracy outcomes are predicted by other academic achievement and demographic variables, but predicted outcomes can change depending on whether the home learning environment is supportive of achievement or not (Melhuish et al. 2008). Similar trends have been found for numeracy, in particular showing that active parental involvement in children's preschool learning has lasting benefits (Carmichael et al. 2014; Casey et al. 2016). Thus, the longstanding moral imperative to coordinate children's learning across the home and preschool contexts (Brooker 2010) also increasingly finds an empirical basis.

Further, there is considerable research indicating that parents want their children to learn numeracy and literacy (Fung and Cheng 2012; O'Gorman and Ailwood 2012). The current intervention capitalised on parents' enthusiasm for their children's learning by asking them to implement part of the intervention.

The Footsteps Project: an intervention to stimulate child-initiated learning

The *Following in Our Footsteps* study (or *The Footsteps Intervention*) sought to address many of the challenges described above. Very few interventions have sought to influence how children play (cf. Bellin and Singer 2006; Morrow 1990). Yet, play is upheld as the principle driver of learning in the early years (Johnson et al. 2012; Walsh et al. 2010). Half a century of research has empirically charted the ways in which play drives learning (Christie 1991; Roskos et al. 2010; Shimpi and Nicholson 2014). Play-based learning presents opportunities for intrinsically motivated, enjoyable and child-driven learning (Burghardt 2011; Monighan-Nourot et al. 1987). Yet, it can be difficult to bring sustained mathematical learning into child-initiated play (Anthony et al. 2015), such as turning a child's interest in Spiderman™ into learning about mathematics (e.g. the masked crusader swinging between Manhattan skyscrapers can only be tenuously linked to, say, counting those buildings). Educators frequently report how difficult it is to link what children are actually interested in to curriculum content (e.g. Anning 2010; Cooney 2004).

To circumvent these difficulties, the *Footsteps* intervention (Colliver and Arguel 2016) sought to investigate if young children's interest in mathematical concepts could be sparked by adult demonstrations of numeracy activities. If children were interested in practical applications of mathematics, then this may be sustained by daily life around them and contribute to continued learning about mathematics. Consistent with dominant ECE philosophy, it assumed that children's positive affect about, and an interest in, numerate practices is more important in the early years than numeracy skills per se (Gibbons 2007; Hedges and Cullen 2012). The intervention sought to test whether adults could influence what children were interested in playing with. Just as children in traditional societies would play with, and consequently learn about, adult-demonstrated work practices, would children participating in the Footsteps intervention play more with numeracy if exposed to adult demonstrations of numeracy practices?

Method

Following in Our Footsteps was a small study with two intervention groups (Numeracy and Literacy) and one Control group. The intervention groups demonstrated literacy and numeracy activities in front of their children with various relevant materials (see Table 1). These demonstrations are described below in relation to typical work post-industrial contexts. The Control group was given the same materials to control for the influence of children's interest in the new materials. Doing so sought to isolate the effect of the mathematics and literacy-related demonstrations from conflation with an interest in the materials per se.

Work-related problem-solving

Most work in post-industrial societies requires basic literacy and numeracy skills to solve daily work problems. These skills are basic to compulsory schooling (ACARA 2014), and their beginnings are advantageous when young children start school (Thorpe et al. 2004). The study described here linked literacy and numeracy with basic problems that adults encounter at work in post-industrial societies, such as basic calculation and writing a message to a colleague. For example, being able to measure size or quantity and divide this into equal parts—a skill necessary for many work tasks such as calculating how many bricks would be required to build a wall, or how many pens to buy for a work team, for example—was represented in simple dialogue between two adults in families in the Numeracy group. The skills needed for these problems are evident in the scripts used for the demonstrations (see Appendix 1 and 2).

Participants

The Footsteps intervention approached three randomly chosen ECE centres in areas with similar demographics in suburban Sydney (Australia). Centres that were using targeted numeracy or literacy programs (e.g. *Early Learning Languages Australia*) were not recruited to ensure any positive results were not attributable to these programs. Directors were invited to participate in the study. Once director consent was attained, educators and family members of 4-year-old children were invited to participate. For the purposes of this small study, 17 children, their parents and six educators volunteered to participate. In two of the three groups, an extra child was recruited to compensate for two other children diagnosed with attention disorders. Parents and educators received training on the intervention strategy for their group (Literacy, Numeracy or Control) randomly allocated to their centre. Centres were comparable in terms of socio-economic status as all three were within the same postcode and area of high 'white collar' employment. The sample of our study was hence composed of 17 children, allocated to the groups Numeracy ($n = 6$), Literacy ($n = 5$) and Control ($n = 6$), with a balance of gender (F = 7, M = 10) and age (M = 4;1 years old). See Table 2.

Ethical approval

Before the study began, the University's Human Research Ethics Committee approved ethical considerations of the study (Reference No. 5201500913). Once written participant consent was obtained, information letters were sent out to families and educators, who were asked to ascertain if their child consented to participate. On-going child consent was sought every time the researcher collected data, using a child-friendly 'OK sheet' (Harcourt 2011, p. 336) that allowed children to verbally or non-verbally opt out of the research at any point (Colliver 2017).

Procedure

In homes and ECE centres, parents and educators of participating children demonstrated literacy or numeracy problem-solving activities for 15 min, three times a week for 4 weeks, in each setting. Participants were provided with professional development videos instructing them how to follow the scripts provided. After using the scripts several times, it was expected that they would memorise the ways in which the problem-solving activities were articulated and apply the scripts to different practical contexts (e.g. patterns using cutlery, bricks and chalk, jumping and hopping etc.). However, demonstrations remained similar because variations were miniscule (i.e.

Table 2 Child participant ages and sex

Group	Literacy	Numeracy	Control
Girls	$n = 3$	$n = 2$	$n = 4$
Boys	$n = 2$	$n = 4$	$n = 2$
Age	M = 4;3 years, SD = 0.26	M = 4;0 years, SD = 0.29	M = 4;1 years, SD = 0.23

content remained largely consistent over different contexts). Scripts used only literacy or numeracy problems (depending on the group they belonged to; see Appendix 1 and 2). There was no script for the Control. Two family members[1] and two educators of each child demonstrated in pairs in order to verbalise problems and solutions for children to hear. Parents demonstrated in homes and educators in ECE centres.

It was important that adults showed interest in and valued the problem-solving activities. Because the study was testing the effects of children's observation of the practices demonstrated, parents and educators in all three groups (Literacy, Numeracy, Control) were instructed to restrict children (including siblings or classmates) from joining in during the demonstrations. If not, parents may have been tempted to guide children and so generate bigger effects on their learning than what was expected from mere demonstration. Participants were instructed to demonstrate nearby when children were occupied (e.g. involved in construction play) but not distracted (e.g. video games, television). Adults were not to deliberately draw attention to the demonstrations, but carry them out as activities valued regardless of whether children appeared to be paying attention to them. Whenever adults were not using materials for the 15-min demonstrations (see Table 1), they made the materials available to children along with the children's other toys and materials (e.g. in children's normal toy box). Adults were instructed to tell children to wait until the demonstrations were over if they requested to play with the materials, in this way showing the value of the activities while also eliminating any possible impacts of the adults indirectly encouraging children to play with the materials. To ensure no extraneous influences on children's play and numeracy and literacy levels over the 4-week study period, parents and educators in all three groups were requested to continue whatever educational programs or games children were already doing, and to not begin any new literacy- or numeracy-based activities other than the demonstrations.

Measures

Numeracy was assessed before and after the 4-week intervention using the Early Mathematical Patterning Assessment (EMPA; Papic 2013). EMPA scores before school are shown to predict general mathematics abilities 1 year later and are thus seen as a good indication of early mathematical ability (Papic 2013).

Literacy was assessed before and after the intervention using the iPad™ version of the Letter and Word Recognition (LWR) and Written Expression (WE) subtests of the Kaufman Test of Educational Achievement (KTEA)-III, suitable for children as young as 4 (Kaufman and Kaufman 2014). The KTEA-III uses Growth Scale Values (GSVs) to compare literacy improvements relative to improvements from a standardised sample of the age group of the individual participant. Pre- and post-tests were administered in distinct forms with 'very few to no overlapping items' (p. 34). Pre- and post-tests were designed to be equivalent if re-administered within 30 days. Due to the inconvenience of participants demonstrating for a longer period, the intervention was conducted for 4 weeks.

In addition to assessing literacy (in Literacy and Control groups) and numeracy (Numeracy and Control), the time children spent playing with numeracy- or literacy-

[1] One mother demonstrated using a sock-puppet as her partner when the father was unavailable.

related content during their free play time at the centre (3 to 5 days/week) was recorded also. After undergoing training, the children's educators (n = 6; two per centre) noted the number of times and minutes during which children's freely chosen play resembled the activities in the demonstrations (educators in the Control group noted play related to any form of numeracy or literacy). They observed children during their free playtime at the centre (roughly 3 h per day). Because the amount of time parents had to observe their children was highly variable for each family, the study only measured activities resembling the demonstrations during free play at the ECE centre.

Participant interviews were conducted immediately after the study (i.e. within 7 days) and again 3 months after the study. This allowed for qualitative descriptions of the immediate and longer-term impacts of the intervention on children, parents and educators. To ensure greater credibility of responses, an external research assistant (without investment in the result) conducted the interviews.

Analysis

Data from the two children diagnosed with attention disorders were removed from the pool of data. Because of the limited sample size remaining (N = 15), the quantitative analyses did not involve parametrical statistical tests. The total minutes played (with literacy or numeracy activities) were hence analysed non-parametrically using a Kruskal-Wallis H test. Because some children spent more days at the centre than others, the average playing time was analysed per day.

Literacy measures were obtained from the LWR and the WE results. The GSV accounts for normal literacy development that would have occurred without the intervention effects (Kaufman and Kaufman 2014). Raw EMPA scores were used to measure numeracy. Participant interviews (see Appendix 3) were analysed inductively (Pope et al. 2000) by an external research assistant in relation to the impact and sustainability of the intervention.

Results

The data collected throughout the intervention sought to show whether intervention groups would differ significantly from the control group on (a) measures of minutes spent *playing with* (1) numeracy or (2) literacy content and (b) *ability* measured in scores of (1) numeracy (EMPA) or (2) literacy (KTEA-III). Post-study interviews also provided data about these two factors across the two intervention groups.

Time spent playing with numeracy or literacy

Participating educators (n = 2 per centre) observed participating children's free play at the centre (a) before (one baseline week, as reference level for any changes later) and (b) during the intervention (4 weeks). At baseline, there was no significant difference of time spent playing with numeracy content between the Numeracy and Control groups (M = 11, $p = 0.31$), nor of time spent playing with literacy content between the Literacy and Control groups (M = 14, $p = 0.93$). See Fig. 1.

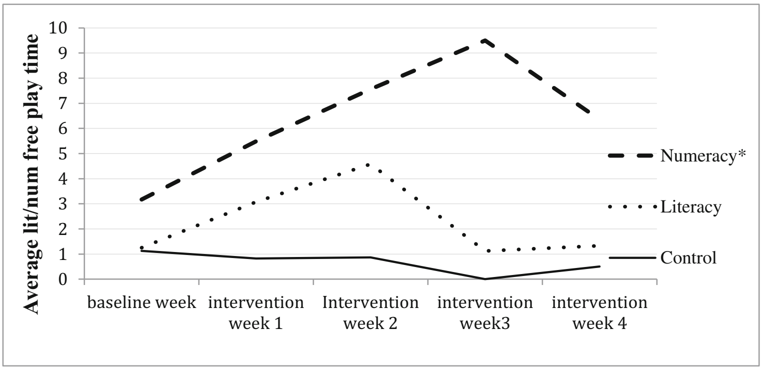

Fig. 1 Average time each group played with literacy and/or numeracy per day (min)

For total time spent playing over the whole 4 weeks, a Kruskal-Wallis *H* test showed that there was a statistically significant difference between the three groups, $\chi^2(2) = 8.612$, $p = 0.013$, with a mean rank time score of 13.67 for the Numeracy Group, 7.8 for the Literacy Group and 5.33 for the Control Group (Fig. 2).

A pair-wise comparison (Mann-Whitney test) of time engaged in numeracy- or literacy-related play in the Literacy and Control groups did not show any significant differences (M = 11, $p = 0.53$). However, children in the Numeracy group spent significantly more time per day playing with numeracy content than did the Control group children with numeracy or literacy content, $M = 0$, $p = 0.002$ (Fig. 2, where * indicates significance at $p < 0.005$).

Influence on children's literacy and numeracy abilities

To assess the improvement of numeracy and literacy skills following the 4-week intervention, we considered the difference between pre- and post-test scores for each of the variables from the EMPA and the KTEA-III. A pair-wise comparison of Numeracy and Control (Mann-Whitney test) did not show any significant improvement in EMPA score between these groups ($M = 13$, $p = 0.48$; see Table 3). A pair-wise comparison (Mann-Whitney test) of Literacy and Control groups showed a significant difference of LWR scores between these groups before and after the 4-week intervention ($M = 1.5$, $p = 0.009$). However, the pair-wise comparison (Mann-Whitney test) between the Literacy and Control groups did not show any significant difference of WE scores between these groups ($M = 13$, $p = 0.79$). The Growth Scale Value (GSV)

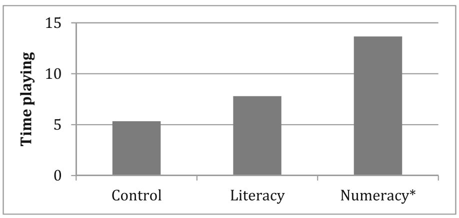

Fig. 2 Total time engaged in play related to literacy and/or numeracy (min)

Table 3 Means (SD) of pre-/post-intervention differences for EMPA, WE and LWR scores according to the groups

Group	*n*	EMPA change	WE change	LWR change
Literacy	5	N/A	3.8 (7.29)	3.4 (6.3)*
Control	6	0.12 (0.13)	0.66 (9.7)	−5.33 (4.41)
Numeracy	6	0.09 (0.17)	N/A	N/A

changes for LWR and WE appeared higher for participants in Literacy, but pairwise comparisons of Literacy and Control (Mann-Whitney test) showed a significant difference only for GSV-LWR score changes between the groups ($M = 4.5$, $p = 0.05$).

Educator and family evaluations

Post-intervention interviews revealed 81.8% of adult participants in the two intervention groups observed an increase in their child's interest in numeracy or literacy, which is consistent with the quantitative data (e.g. see Fig. 1). Also consistent with the data, no parents in the Control group reported increases in interest (although two parents reported some initial interest in the materials). There was also a 96% agreement between parent and educator reporting of individual children's progress, with an inter-rater reliability Cohen's Kappa of $k = 0.8$.

As well as increased interest in numeracy and literacy, 64% of parents reported increased abilities in numeracy or literacy that they attributed to the Footsteps intervention. The sentiment was echoed in the reports from the educator in the Numeracy group:

> They [the participating children] have gotten better at the patterns. Not everyone [who participated], but most of them (Numeracy group Educator One, 8:00#2, three months after)

Many parents reported a change in the way they think about how they should interact with their children:

> Definitely there will be a change in what I expose [my son] to after the study. …. Before I used to make him sit and study, but now playing with the blocks he is so happy and he can answer questions about simple patterns (Numeracy group Parent Five, 10:47#2)

> This whole observation learning is something we've learned from, we use it to try and get her interested in words… She copies us, and it helps her in other areas (Literacy group Parent Five, 7:30#2)

One final finding of relevance was that no parents or educators reported any negative effects of the intervention: at worst, Footsteps was an innocuous and inexpensive intervention.

Discussion

The Footsteps intervention was designed to circumvent some of the identified challenges of early mathematics teaching. While there is some limited evidence that programs focussing on numeracy skills boost numeracy outcomes (Meiers et al. 2013; National Research Council 2009), the importance of the early years for a range of outcomes would suggest this approach unwise when knowledge about literacy, health, emotions and one's world in general is so crucial (Campbell et al. 2001; Shonkoff et al. 2009; Vassallo et al. 2014). It is also deemed more important to create positive attitudes and dispositions towards mathematical learning than it is to acquire specific content knowledge and skills (Gibbons 2007; Hedges and Cullen 2012).

Due to the benefits of intrinsically rather than extrinsically motivated learning (Habgood and Ainsworth 2011), child-initiated mathematical interventions are likely to be more effective than adult-initiated ones. The challenge is how to 'inspire'—rather than force—children to initiate mathematical learning. The best avenue appears to capitalise on what history shows is children's tendency to imitate adult work practices in their freely chosen play (Elkonin 2005). The model proposed in this paper tested whether this tendency could be utilised: by exposing children to more literacy- and numeracy-based problems that adults solve in their daily work. If this tendency was effective, there may be no need to force (or even encourage) children to partake in the activities, as children would naturally be inclined to imitate them. To test the effectiveness of this model, the Footsteps intervention systematically exposed children to adult demonstrations of numeracy and literacy activities using relevant materials in the home and ECE centre.

Interest in mathematical learning

Results suggest exposure to adults engaging in mathematical pattern problem-solving influenced children to play with the same materials, significantly extending their play-based exploration of patterns and mathematical concepts (see Fig. 1) compared to their pre-intervention play. A similar pattern was evident with literacy. Although the increase was not statistically significant, demonstrations of literacy problems also appeared to provoke children to choose more literacy-related play topics than the Control group, even though those demonstrations were often independent of the children (Colliver and Arguel 2016).

These findings are important because parents and educators did not encourage children to play with the patterning or writing, often demonstrating when children were otherwise occupied with other activities. This adds weight to the finding that adults themselves using mathematics in everyday life can have a powerful impact on what children want to learn about. The observational roots of children's motivations may be an under-utilised aspect of early learning.

Vygotsky (1933/1967) proposed that children attend to practices they see valued by their culture. Rogoff's research (Gutierrez and Rogoff 2003; Rogoff et al. 2006) suggests they also observe, emulate and learn from these practices. In the Footsteps intervention, participating adults attributed value to literacy and numeracy practices by demonstrating frequently (three times a week for 4 weeks, in both settings) and consistently (for 15 min, minimum). Participating adults prioritised demonstration of these activities over others (e.g. attending to children, such that while demonstrating, adults prevented children from participating by saying 'You can have a turn in a minute but it's really important that Mum and Dad do this right now'). This value attribution was a plausible reason why children appeared to emulate the activities later on. This has interesting implications for mathematical education, which is typically conducted in school settings where adults instruct children to undertake the learning activities rather than use mathematics themselves. Further, not only do the overwhelming majority of parents undertake paid work away from their children, the mathematics they use in their work is likely to be too obscure or difficult to be visible to children. The current findings suggest adults should scrutinise what they are exposing children to and find ways to demonstrate the daily utility of the activities that mathematics education attempts to teach (e.g. recognising order, quantity and pattern; Fox 2006). Such an approach strikes a balance between the traditional adult-initiated teaching of early mathematics and the play-based (and therefore child-initiated) approach that is so dominant in Western ECE curricula (OECD 2006).

The results indicating increased literacy-related play are likely to have occurred because literacy problem-solving was made visible to children. This implies that if adults could make their thinking in everyday uses of literacy much more explicit, then children are more likely to become interested in them. It is probable that attributing social value to this problem-solving is an effective way to foster child-initiated learning, both for literacy and numeracy. The current findings show the positive value of exposing young children to the numeracy and literacy adults use in their everyday life. They urge educators and parents to create opportunities for young children to be exposed to those practices on a regular basis, such as three times a week.

Mathematical abilities

The increased time children spent playing with numeracy and literacy concepts shown in the current results is also significant because freely chosen play is typically seen as a representation of what children are interested in (Wood 2013). It is widely believed that young children seek to understand the world around them through play (Nutbrown et al. 2008; Shimpi and Nicholson 2014). Because there were no significant differences in mathematical abilities between the Numeracy and Control groups, exposure to mathematics demonstrations appeared insufficient to improve children's patterning skills, possibly due to the short time frame (4 weeks) or the lack of applicability of the demonstrations to patterning. Results for the Literacy group, however, suggested their reading abilities significantly increased relative to increases in the Control group. Even in the short period of only 4 weeks, children exposed to literacy problems played more with literacy and learned significantly more as a result. Not only did children appear to learn through play, adults appeared to have inspired that learning. This also speaks of the benefits of children witnessing adults using literacy explicitly. It is worth noting that these demonstrations were done while children were engaged in other activities. In the post-intervention interviews, many parents reported being surprised the demonstrations had an effect because children appeared to be paying attention to what parents and educators did. This suggests that, as adults concerned with children's learning, we should not downplay the benefit of our using numeracy and literacy, nor should we overstate the benefits of making sure children engage in those learning activities while under our supervision. The current results suggest that children's interest alone was enough for them to play with and learn about numeracy or literacy by themselves, without the need for adult initiation/guidance.

Accordingly, 81.8% of parent interviews noted improvements in their child's literacy or numeracy from the intervention. Many parents reported a newfound awareness of the impact of their child witnessing of daily adult practices of literacy or numeracy (see excerpt from *Literacy Group Parent Five* above).

Limitations and implications

The Footsteps study was conducted with a small sample size and findings are preliminary in nature. The increases in play related to literacy appeared to drop in the third week of the intervention, suggesting that for literacy the demonstrations did not sustain the children's interest for the full 4 weeks. A weaker but similar trend may have occurred in the final week of the numeracy demonstrations. Given that the numeracy demonstrations had many more contextual variations possible, these trends suggest that the demonstration content may need to evolve dynamically to sustain children's curiosity for longer periods. Parent and educator interviews 3 months after the intervention suggested that children's interests in numeracy and literacy continued to grow, but these suggestions require empirical verification.

The effects of the study were small and not consistent across all measures (i.e. numeracy abilities were not significantly higher in the numeracy group). A larger study with a longer demonstration period (than 4 weeks) is required to see if it yields significantly improved writing and numeracy skills. Nonetheless, the fact that reading abilities were significantly improved after such a short time is a promising result, suggesting that longer interventions may have even stronger results.

The results do not necessarily imply that adults should not ask children to carry out mathematical learning tasks. But they do imply that it may be unnecessary, rather that socially valued applications of mathematics to everyday life can be sufficient to spark young children's interest and learning. The important thing appears to be that adults value their own participation in numerate activities as much as they do children's.

Given the substantial contribution, educators can make by working with families to provide continuity for children's learning experiences from the ECE centre to the home (Melhuish 2010), the current results provide avenues for educators to do this in ways that fit in well with parents' existing work practices. If educators and parents can find ways to visibly demonstrate the value of literacy and numeracy in everyday life, the current findings suggest this will have positive impacts on what children choose to pursue in their self-initiated play and learning. Mathematics teachers may be able to show parents ways that they can demonstrate their everyday numeracy to children in the home (e.g. calculating grocery prices, finding repeating patterns in building designs, basic budgeting). Teachers could then provide continuity for children by demonstrating similar activities in the classroom.

The results also provoke educators to reconsider traditional adult-initiated approaches to early mathematical learning. Rather than seeing themselves as regulators of children's learning activities, they may also consider how they can demonstrate (in their own activities) the value of the content they teach.

Conclusion

The Footsteps intervention sought to inspire child-initiated mathematical and literacy-based play and learning. It did so by merely changing the activities of the parents and educators. Instead of focussing on children's activities, they attributed social value to numeracy by demonstrating mathematical problem-solving in everyday life, with a particular focus on patterns. Results for mathematics indicated that children spent significantly more time playing with numeracy when they were exposed to the adult demonstrations. While the numeracy scores were not better than the control group, the increased interest shown by children is likely to lead to positive attitudes and dispositions of curiosity towards mathematics in everyday life. It is expected that the positive affect is likely to have a more sustained impact on mathematical learning throughout school than solely mathematical knowledge acquisition in these early years. There were also increases in the literacy version of the demonstrations, and the increased time spent playing with literacy corresponded to reading abilities which were enhanced significantly more than the Control group. While these reading abilities may not be sustained, it is expected that the increased interest in literacy will also lead to sustained literacy learning throughout school. Thus, the increased interest in literacy and numeracy found in the Footsteps intervention suggest adults can have a direct influence on children's interest in mathematics, which may be more likely to be sustained long term by genuine interest and motivation than from adult-initiated mathematics education.

Appendix 1: sample script used in Footsteps Intervention

Adult A and B sit next to each other with coloured blocks

Adult A: *[Adding two blocks to an existing tower of four blocks]* Okay, so that's another green and then blue. That gives us … six blocks

Adult B: Cool! Let's do it with purple and orange! Ok, so can you pass me one of each?

Adult A: I'll put them together for you.

Adult B: So, if we want to make a tower of six blocks using the purple and orange, how many orange blocks will we need?

Adult A: Hmm… I think we need to divide six by the number of blocks in the unit of repeat. So that's one purple and one orange. One, two. So, if we want to divide the six blocks in the tower by two, we'd get that two times. Is that right?

Adult B: Ah… let's see. One, two (once), and one, two (twice) *[demonstrating with two units of repeat]*, then we have one, two, three, four blocks. So NOT six. How many more will be need to make six?

Adult A: I see what you mean. Let me try with another two blocks, one purple, one orange. I'll put them on top of your four blocks. That's one, two (once), one, two (twice), and one, two (three times). Can you count to see if that's six in our tower?

Adult B: Okay: one, two, three, four, five, and six! That's what you wanted, a tower of six blocks! So how many purple blocks did we use?

Adult A: *[Pointing to the purple blocks]* One, two, three. So, there's three! What about the orange blocks? How many are there?

Adult B: *[Pointing]* One, two, three! So, there are the same number! Shall we add another purple and orange block to our tower? That's another two blocks…

Appendix 2: an example excerpt from literacy script

Adult A and B sit next to an art easel with crayons and write on a large piece of paper

Adult A: I want to write 'to Grandma'. I want to start with the word 'to' and want a letter that makes the sound /t/ /t/ /t/. Which letter makes the sound /t/?

Adult B: Hmmm, which letter makes the sound /t/ /t/ /t/? I think it's the letter TEE! Is that right?

Adult A: Letter TEE makes the sound /t/ t/ /t/ … Great! *[Writes the letter t in lower case]*. Now I want to make the word 'to' … and I have the sound /t/ /t/ /t/, … so what letter makes the sound /u:/??

Adult B: Hmmm, which letter makes the sound /u/ /u/ /u/? I think it's the letter YUUU! Is that right?

Adult A: It usually does, but in the word 'to' we use the letter O. So, the word 'to' is spelled TEE OH…. Do you know how to write the letter OH?

Appendix 3: Post Study Interview Questions – Parents

Thank you so much for being part of the study. Your participation has led to some interesting preliminary results!

1. The aims of the study were to see if adult behaviour might affect how children decide to play. Do you think the demonstrations had any effect on [child's name]'s play?
2. How did you find the study?
3. Were you able to do the demonstrations 3 times a week or were you too busy? Did you do more than that?
4. Did you take any notes on changes you noticed in [child's name]'s behaviour? What were they?
5. Did you notice any other changes in her/his behaviour? (ask for specific examples if they talk generally)
6. Was there anything which you felt got in the way of the effects of the study?
7. Were the materials you received a novel/new thing for the child?
8. Were the activities very different to what you were already doing?
9. Did you find it hard to not tell your child to do things?
   a. To ignore them when they wanted to join in on the activities?
10. Any siblings? How did they effect the study?
11. How do you think your child's cultural background impacted on the study?
    a. The impact of the demonstrations
    b. The types of play your child was inclined to partake in
    c. How you interacted with your child?
12. Do you think the study has impacted the way you would like to interact with your children in the future?

13. Do you think you learned anything about your children from doing the activity?
14. Do you think you learned anything about the way that children see their parents?
15. Will this change what you expose your children to?
16. What will you do differently?
17. What were the biggest constraints to doing fifteen minutes of demonstrations three times a week?
18. Do you think the materials you were given will be useful in the future?
19. Do you think you got anything else from the study?
20. Anything else which you would like to add?

Thank you for your time today and for your interest in the study.

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