What is Mathematics Education for Children under Three? A Snapshot of Findings from a National Survey

Amy MacDonald
Charles Sturt University
<amacdonald@csu.edu.au>

There is clear evidence that early mathematical development sets the foundation for success in later mathematics learning; however, there is little research which considers mathematics education for children under three years of age. This paper provides a snapshot of findings from a national survey of early childhood educators conducted as part of an Australian Research Council *Discovery Early Career Researcher Award* (DECRA) project titled, 'What is mathematics education for babies and toddlers?' The larger project is investigating mathematics education for children under three and interrogating the mathematics education beliefs and practices of the educators who work with these children. This paper presents some preliminary findings from a survey of 506 Australian early years educators to establish a baseline position regarding mathematics education for children under three years of age. Initial analyses offer some promising findings about the state of early childhood mathematics education in Australia. Educators display positive beliefs and self-understandings about mathematics, and utilise a range of everyday activities and resources for mathematics education; all of which are important starting points for high-quality, meaningful mathematics education with our youngest children.

Introduction

This paper provides a snapshot of findings from a national survey of early childhood educators conducted as part of an Australian Research Council *Discovery Early Career Researcher Award* (DECRA) project titled, 'What is mathematics education for babies and toddlers?' The project is investigating mathematics education for babies and toddlers (children aged under three years; henceforth "Under 3s"), and interrogating the mathematics education beliefs and practices of the educators who work with these children. In Australia, more than 22% of babies (under 2 years of age) and 54% of toddlers (2-3 years of age) attend a formal early childhood education service (Australian Bureau of Statistics, 2014). This DECRA study is determining when, and how, mathematical learning experiences are provided for children in a range of Under 3s education settings. This is crucial because there is clear evidence that early mathematical development sets the foundation for success in later mathematics learning (Duncan et al., 2007; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006). However, there is little research which considers mathematics education for children under three years of age. To date, early childhood mathematics education research has largely focused on the preschool and early schooling years (ages 4-8). A key finding of the research around children aged 4-8 is that many children already know much of what they are to be *taught* in their first year of school (Gervasoni & Perry, 2015; MacDonald & Carmichael, 2015). Thus, it is imperative that we gain a robust understanding of when, and how, children are provided with mathematical learning experiences in early childhood education settings *prior* to four years of age. This paper presents data from a national survey to address the following research question: What are early childhood educators' beliefs and self-understandings about mathematics education for children under three years of age?

2019. In G. Hine, S. Blackley, & A. Cooke (Eds.). Mathematics Education Research: Impacting Practice *(Proceedings of the 42nd annual conference of the Mathematics Education Research Group of Australasia)* pp. 468-475. Perth: MERGA.

Background

Early Childhood Reform Agenda

The introduction of the early childhood education and care reform agenda in 2009 (Council of Australian Governments, 2016) brought substantial changes to the Australian early childhood sector; but many of the benefits are yet to be fully realised, particularly for children under three. Despite the requirement for a proportion of educators to be university qualified, Under 3s settings are consistently staffed by the least-qualified educators (Elliott, 2006). National assessment data from the Australian Children's Education and Care Quality Authority (ACECQA) shows that 1 in 6 centres have not met the educational program and practice National Quality Standard (ACECQA, 2018). Furthermore, research suggests that many early childhood educators are reluctant to engage in intentional teaching of mathematics (Lee & Ginsburg, 2009). This reluctance may be due to concerns about overly didactic programs, limited awareness of the mathematics with which children engage, privileging other parts of the curriculum (for example, language and literacy), and teachers' anxieties about their own mathematics knowledge (Cohrssen, Church, Ishimine, & Tayler, 2013). A further challenge is that those educators who *do* include mathematics education as part of their curriculum typically hold a very narrow view of what constitutes mathematics, stressing the ability to count and knowledge of numbers (Department for Education and Child Development, 2012). As such, a key challenge in the current reform climate is to promote educator knowledge about early childhood mathematics as a means of providing children with access to high-quality mathematics education.

Mathematical Capabilities of Babies and Toddlers

International research has shown that children begin developing mathematical skills and competence in regards to a range of mathematical concepts and processes from a very young age. Cognition research has demonstrated that babies, from birth, are capable of detecting numerical correspondences and abstract properties of objects and events (Starkey et al., 1990). In a study of children aged between 30 and 33 months, Reikerås, Løge, and Knivsberg (2012) found that toddlers showed mathematical competencies in number and counting, geometry, and problem solving. Björklund's (2008) study of children aged between 13 and 45 months demonstrated that toddlers interact with concepts of dimensions or proportions, location, extent, succession, and numerosity, and use a range of strategies to express their understanding.

Early Childhood Mathematics Education

Doig, McCrae, and Rowe (2003) have suggested several reasons for the importance of understanding children's mathematical development in the years prior to school, including the increasing number of children participating in early childhood programs and growing recognition of the importance of mathematics in general. There is general agreement that young children are capable of accessing powerful mathematical ideas and should be given the opportunity to access these ideas through high quality child-centred activities in their homes, communities, and prior-to-school settings (Hunting et al., 2013).

Early Mathematics and Later Outcomes

A growing body of research demonstrates the predictive power of early mathematical competencies for later academic outcomes. Children who enter school with high levels of mathematical knowledge maintain these high levels throughout, at least, their primary school

education (Baroody, 2000; Klibanoff et al., 2006). Watts, Duncan, Siegler, and Davis-Kean (2014) found that there were statistically significant associations between preschool mathematics ability and adolescent mathematics achievement. In a study of school readiness and later achievement, Duncan et al. (2007) found a strong correlation between early mathematics skill and later mathematics achievement, as well as associations between early maths and other competencies such as reading and writing. MacDonald and Carmichael's (2015) examination of teacher-reported data for 6,511 children participating in the *Longitudinal Study of Australian Children* (LSAC) found that children possess a range of mathematical competencies at ages 4-5 years, and 98% of the children in the study showed *interest* in mathematics at this age. This is an important finding because other studies have shown that levels of mathematics understandings decline over the entire school period (Fredricks & Eccles, 2002), but that if children engage in meaningful and enjoyable mathematics education in the early years, they are much more likely to appreciate, and engage in, later mathematics education (Linder, Powers-Costello, & Stegelin, 2011).

Methodology

Conceptual Framework

The DECRA study combines concepts from two theoretical perspectives—ecological theory (Bronfenbrenner, 1974) and practice architectures (Kemmis, 2007, 2008)—in order to consider early childhood mathematics education *in context*. Bronfenbrenner (1974) describes three key elements of contexts: activities in which the child is engaging ("activities"); people, in differing roles and relationships with the child ("interactions"); and the physical space and materials within this ("settings"). Within these settings, the beliefs and practices of early childhood educators guide the mathematics education opportunities available to the children with whom they work. In order to explore these practices, the study adopts the concepts of "sayings, doings, and relatings" from the theory of Practice Architectures (Kemmis, 2007). These concepts provide a framework for recognising and interpreting early childhood educators' own particular understandings and self-understandings ("sayings"); skills and capabilities ("doings"); and values and norms ("relatings") (Kemmis, 2008).

Research Design

The larger DECRA project employs a multi-phase mixed-method design to investigate children's mathematical activities and interactions, and educators' beliefs and practices. Participants in the larger study have been recruited from a range of early childhood service types, including long day care, family day care, and supported playgroups. The project specifically targets a range of services in order to capture typical Under 3s education settings and identify the enablers and constraints of mathematics education in everyday situations. This paper focuses on Phase 1 of the project which consisted of a national survey of early childhood educators to ascertain their beliefs and practices regarding mathematics education for babies and toddlers. The national survey sought the perspectives of the Australian early childhood education field; as such, it included educators of children aged from birth to 8 years, as well as those who are currently working with children under 3. The survey was adapted from Maier, Greenfield, and Bulotsky-Shearer's (2013) *Preschool Teacher Attitudes and Beliefs towards Science* (P-TABS) questionnaire, and consisted of demographic and contextual questions, responses to Likert scales, short-answer responses, and open comment prompts. A set of questions was asked of the full sample of the Australian early childhood sector, and an additional sub-set of questions was directed only to those

respondents currently working in an Under 3s educational setting. The survey was completed by a total of 506 respondents, and 195 respondents of the total sample are current Under 3s educators. Early childhood educators from a variety of services (for example, family day care, long day care, preschools, and primary schools) in a range of communities across all states and territories of Australia have completed the survey. For the purpose of this paper, the data has been analysed descriptively to establish a baseline position on educators' beliefs and self-understandings about mathematics education for Under 3s.

Results

This section presents a snapshot of descriptive data from both the full sample as well as the additional questions for the sub-sample of current Under 3s educators. These data provide demographic information as well as patterns of responses in relation to participants' beliefs and self-understandings about mathematics education for Under 3s.

Demographic Overview

The full sample consists of 506 respondents. Of these, 479 (94.9%) are female, 21 are male, 3 are gender diverse/non-conforming, and 3 preferred not to answer. Responses were received from educators in all states and territories; however, the majority of respondents were from NSW (53.1%) or VIC (33.1%). The majority of respondents (55.7%) have a Diploma qualification, 39.9% have a 3- or 4-year Bachelor degree, and 20.8% have a Certificate III. It should be noted that 65.4% of respondents are currently studying for a 4-year Bachelor degree, in line with the early childhood reform agenda. As shown in Figure 1, most of the full sample currently work in the early childhood sector.

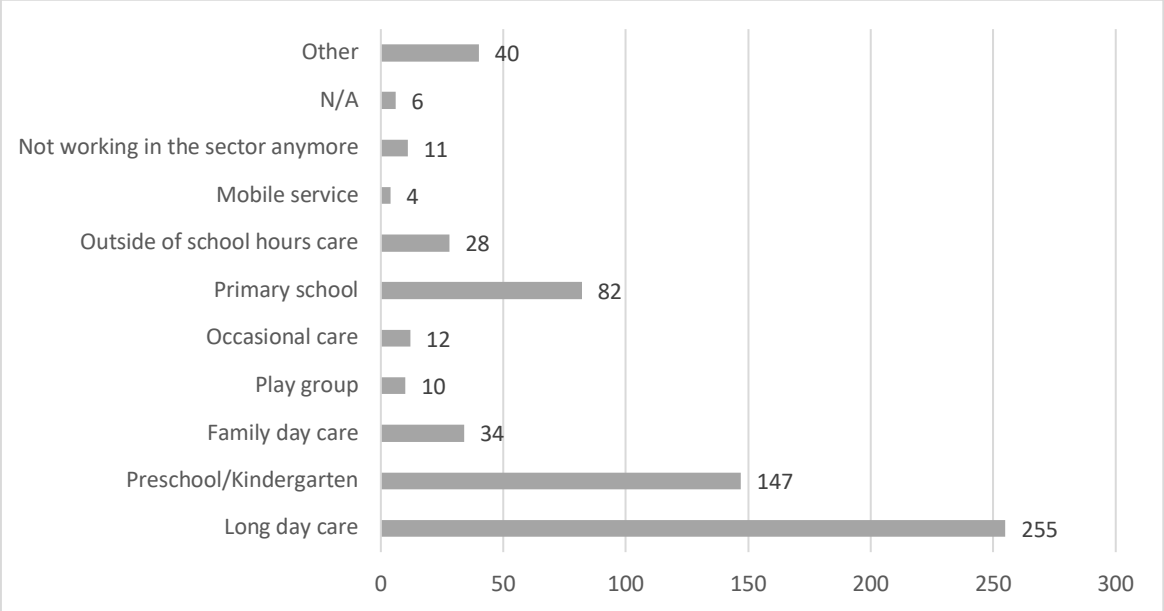

Figure 1. Type of service in which respondents work.

Beginnings of Mathematical Exploration

Educators were asked to indicate the age at which they believe children begin to explore a range of mathematical ideas. Table 1 shows the patterns of responses to this question. Figures highlighted in bold indicate the highest response for each topic. It can be seen that the majority of respondents believe that children begin exploring all of these topics when they

are younger than two, and most believe that patterns, shapes, and locations are explored prior to one year of age.

Table 1
Age at which children begin to explore mathematical ideas (N=477)

Topic	< 1 year	1-2 years	2-3 years	> 3 years
Numbers	41.1%	**41.5%**	14.1%	3.4%
Counting	34.8%	**49.1%**	14.9%	1.3%
Patterns	**49.3%**	25.8%	16.4%	8.6%
Shapes	**49.7%**	36.3%	12.4%	1.7%
Location	**52.0%**	21.2%	14.3%	12.6%
Measuring	24.7%	**35.9%**	24.7%	14.7%
Matching and sorting	34.0%	**41.1%**	20.8%	4.2%

Beliefs and Self-Understandings about Early Childhood Mathematics Education

The full sample were invited to respond to a number of prompts about their beliefs and self-understandings about mathematics education for very young children. These prompts were adapted from Maier et al.'s (2013) P-TABS instrument. Table 2 shows the extent to which respondents agree with the listed statements and majority responses are bolded. It seems that over 90% of respondents agree that Under 3s are curious about mathematics, and that more maths should be explored with babies and toddlers. There was strong agreement (94%) that maths is not too hard for babies and toddlers. There was also strong agreement that early childhood mathematics education offers a number of benefits; namely, interest in maths when children start school (86.7% agreement), improved language skills (91.4% agreement), and improved social skills (81.3% agreement). Only 11.3% indicated some degree of fear that children may ask them a question about maths that they cannot answer.

Table 2
Beliefs and self-understandings – full sample (N=466)

	Really Disagree	Kind of Disagree	Not Sure	Kind of Agree	Really Agree
Preschool maths activities help children to be interested in maths when they go to school.	2.6%	5.2%	5.6%	26.0%	**60.7%**
More maths should be explored with babies and toddlers.	1.1%	2.8%	5.8%	26.4%	**64.0%**
It is not appropriate to explore maths with children under 3.	**83.9%**	10.5%	2.2%	1.5%	1.9%
Maths activities help improve under 3's language skills.	1.1%	1.7%	5.8%	22.3%	**69.1%**
Young children cannot learn about maths until they are able to read.	**89.9%**	7.1%	0.9%	1.1%	1.1%
Maths activities are too hard for babies and toddlers.	**78.3%**	15.7%	2.4%	1.7%	1.9%
Maths activities help improve under 3's social skills.	2.8%	2.6%	13.3%	36.9%	**44.4%**
I'm afraid that children might ask me a question about maths that I can't answer.	**69.5%**	12.0%	7.1%	7.9%	3.4%
Children younger than 3 are curious about maths.	1.3%	1.5%	6.9%	23.4%	**67.0%**

An extended survey was completed by a sub-sample of current Under 3s educators. These educators were invited to respond to a number of additional items to ascertain their beliefs and self-understandings about their current mathematics education practice with children under three years of age. These items were also adapted from the P-TABS instrument. Table 3 shows the extent to which respondents agree with the listed statements. These data indicate a high level of comfort among the respondents, with the majority feeling comfortable planning (88.8% agreement) and doing (90.1% agreement) maths activities with Under 3s, and using mathematical tools (92.8% agreement). Educators seem to get ideas from what the babies and toddlers do, say, and ask (92.7% agreement), and use all kinds of materials for their maths activities (94.3% agreement). The majority disagree (86.5%) that specialist resources are required to teach maths. Importantly, 94.3% of the sample indicate that they enjoy exploring maths with their babies and toddlers.

Table 3
Beliefs and self-understandings – Under 3s sample (N=195)

	Really Disagree	Kind of Disagree	Not Sure	Kind of Agree	Really Agree
I feel comfortable planning maths activities for babies and toddlers.	2.1%	2.6%	6.7%	30.8%	**58.0%**
It is important for my setting to have a maths area that can be freely explored by the babies and toddlers.	3.1%	4.7%	8.3%	26.4%	**57.5%**
There is not enough time in the day to explore maths with the babies and toddlers.	**57.0%**	24.9%	5.2%	7.3%	5.7%
I use all kinds of materials for maths activities with babies and toddlers.	0.5%	2.1%	3.1%	28.5%	**65.8%**
Preparation for maths education takes more time than other areas.	**45.1%**	34.2%	9.3%	6.7%	4.7%
I feel comfortable doing maths activities in my setting.	2.1%	3.6%	4.2%	26.4%	**63.7%**
I have enough maths knowledge to explore maths with young children.	2.1%	3.1%	6.3%	33.9%	**54.7%**
I feel comfortable using tools such as scales, measuring cups and rulers with young children.	1.0%	2.1%	4.2%	21.4%	**71.4%**
I get ideas for maths activities from what my babies and toddlers do, say, and ask.	1.0%	1.6%	4.7%	35.2%	**57.5%**
I include some books about maths during storytime.	2.6%	2.6%	4.7%	33.7%	**56.5%**
I enjoy doing maths activities with my babies and toddlers.	0.5%	1.6%	3.6%	25.9%	**68.4%**
I need specialist resources to teach maths.	**56.8%**	29.7%	5.7%	6.3%	1.6%
I make an effort to include some maths activities throughout the week.	1.0%	3.1%	3.6%	32.6%	**59.6%**
I collect materials and objects for use in maths activities.	0.5%	2.6%	5.2%	34.7%	**57.0%**
I document children's maths learning (eg. observations, learning stories, portfolios).	1.6%	3.1%	4.7%	25.4%	**65.3%**

Discussion and Conclusion

This paper offers a baseline position in terms of Australian early childhood educators' beliefs and self-understandings regarding mathematics education for children under three years of age. Although these preliminary analyses present only descriptive data, the findings are

overwhelmingly positive. Counter to existing research that indicates fear/disinterest/lack of recognition of mathematics among early childhood educators, this large sample of Australian educators seem to be positive and perceptive about mathematics. Of particular note is the high level of comfort among the Under 3s sample. However, it should be acknowledged that high self-efficacy may be a limitation of a volunteer sample.

These findings also demonstrate a good level of recognition of very early mathematical development. The data presented in Table 1 indicates that the majority of respondents believe children begin exploring a range of mathematical ideas before two years of age. Further analysis of these data will break down the matrix of responses to identify patterns by sector, qualification, role, and so forth.

Data from the sub-sample of current Under 3s educators indicates a good degree of utilisation of everyday resources and activities, which has been advocated for in existing studies (for example, Gervasoni & Perry, 2015). It is important to note the recognition by these educators that mathematics education does not require specialised resources, indicating an ability to capitalise upon the mathematics in the everyday lives of young children. Moreover, this data suggests that current Under 3s educators are comfortable in gaining ideas from babies and toddlers, which is a very positive step in providing meaningful mathematics education for these very young children.

Finally, it is encouraging to note the high level of agreement regarding the additional benefits of mathematics education in relation to transition to school, language development, and social skills. These findings are positive in light of existing research that suggests that educators may prioritise these areas over mathematics. Findings from this study could be used to reinforce the mutually-beneficial relationship between early childhood mathematics education and other aspects of children's learning and development.

In conclusion, these preliminary analyses offer some promising findings about the state of early childhood mathematics education in Australia. Educators' positive beliefs and self-understandings are an important starting point for high-quality, meaningful mathematics education with our youngest children. More complex and theory-driven analyses of the survey data, including the open response text, in conjunction with the larger DECRA study will reveal further insights into when and how these educators are providing mathematical learning experiences for children under three.

Acknowledgments

This project is funded by the Australian Research Council (DE180100399). The author would like to acknowledge the assistance of Steve Murphy in this research.

References

Australian Bureau of Statistics. (2014). *Childhood education and care, Australia, June 2014*. Retrieved from: http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4402.0Main+Features1June%202014?OpenDocument

Australian Children's Education and Care Quality Authority (ACECQA). (2018). *NQF Snapshot Q4 2018*. Retrieved from: https://www.acecqa.gov.au/sites/default/files/2019-02/NQFSnapshot_Q42018.pdf

Baroody, A. (2000). Does mathematics instruction for three-to five-year-olds really make sense? *Young Children, 55*(4), 61-67.

Björklund, C. (2008). Toddlers' opportunities to learn mathematics. *International Journal of Early Childhood, 40*(1), 81-95.

Bronfenbrenner, U. (1974). Developmental research, public policy, and the ecology of childhood. *Child Development, 45*, 1-5.

Cohrssen, C., Church, A., Ishimine, K., & Tayler, C (2013). Playing with maths: Facilitating the learning in play-based learning. *Australasian Journal of Early Childhood, 38*(1), 95-99.

Council of Australian Governments. (2016). *Reform agenda: Early childhood*. Retrieved from: https://www.coag.gov.au/early_childhood

Department for Education and Child Development. (2012). *Numeracy and literacy: Improving Foundation skills for learning and life*. Adelaide, SA: Author.

Doig, B., McCrae, B., & Rowe, K. (2003). *A good start to numeracy: Effective numeracy strategies from research and practice in early childhood.* Retrieved from: http://www.dest.gov.au/archive/schools/publications/2003/goodstart.pdf

Duncan, G.J., Dowsett, C.J., Claessens, A., Magnuson, K., Huston, A.C., Klebanov, P., Pagani, L.S., et al. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428-1446.

Elliott, A. (2006). *Early childhood education: Pathways to quality and equity for all children*. Camberwell, VIC: ACER Press.

Fredricks, J.A., & Eccles, J.S. (2002). Children's competence and value beliefs from childhood through adolescence: Growth trajectories in two male-sex-typed domains. *Developmental Psychology, 38*(4), 516-533.

Gervasoni, A., & Perry, B. (2015). Children's mathematical knowledge prior to starting school and implications for transition. In B. Perry, A. MacDonald, & A. Gervasoni (Eds.), *Mathematics and transition to school: International perspectives* (pp. 47-64). Singapore: Springer.

Hunting, R., Bobis, J., Doig, B., English, L., Mousley, J., Mulligan, J., Papic, M., et al. (2013). *Mathematical thinking of preschool children in rural and regional Australia.* Camberwell, VIC: ACER Press.

Kemmis, S. (2007). *Action research as a practice-changing practice*. Retrieved from: http://www.infor.uva.es/~amartine/MASUP/Kemmis_2007.pdf

Kemmis, S. (2008). Praxis and practice architectures in mathematics education. In M. Goos, R. Brown, & K. Makar (Eds.), *Proceedings of the 31st annual conference of the Mathematics Education Research Group of Australasia* (pp. 17-28). Brisbane: MERGA.

Klibanoff, R.S., Levine, S.C., Huttenlocher, J., Vasilyeva, M., & Hedges, L.V. (2006). Preschool children's mathematical knowledge. *Developmental Psychology, 42*(1), 59-69.

Lee, J.S., & Ginsburg, H.P. (2009). Early childhood teachers' misconceptions about mathematics education for young children in the United States. *Australasian Journal of Early Childhood, 34*(4), 37–45.

Linder, S.M., Powers-Costello, B., & Stegelin, D.A. (2011). Mathematics in early childhood: Research-based rationale and practical strategies. *Early Childhood Education Journal, 39*, 29-37.

MacDonald, A., & Carmichael, C. (2015). A snapshot of young children's mathematical competencies. In M. Marshman, V. Geiger, & A. Bennison (Eds.), *Proceedings of the 38th annual conference of the Mathematics Education Research Group of Australasia* (pp. 381-388). Sunshine Coast, QLD: MERGA.

Maier, M.F., Greenfield, D.B., & Bulotsky-Shearer, R.J. (2013). Development and validation of a preschool teachers' attitudes and belief toward science teaching questionnaire. *Early Childhood Research Quarterly, 28*, 366-378.

Reikerås, E., Løge, I. K., & Knivsberg, A. (2012). The mathematical competencies of toddlers expressed in their play and daily life activities in Norwegian kindergartens. *International Journal of Early Childhood, 44,* 91-114.

Starkey, P., Spelke, E.S., & Gelman, R. (1990). Numerical abstraction by human infants. *Cognition, 36*, 97-127.

Watts, T.W., Duncan, G.J., Siegler, R.S., & Davis-Kean, P.E. (2014). What's past is prologue: Relations between early mathematics knowledge and high school achievement. *Educational Researcher, 43*, 352-360.