COVER SHEET

21ST CENTURY CHILDREN, NUMERACY AND TECHNOLOGY: AN ANALYSIS OF PEER-REVIEWED LITERATURE.

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Technology has catapulted young children into a society where numeracy practices are integral to their everyday lives and future success. In order to determine the scope and foci of the literature on early childhood digital-numeracies, this study examines the articles published between 2000 and 2005 in the ERIC database and proceedings of the annual conferences of the International Group for the Psychology of Mathematics Education [PME]. Overall, this study revealed (1) a lack of peer-reviewed articles that discuss, investigate, or examine early childhood digital-numeracies; (2) an absence of studies on the prior-to school years, and (3) an absence of research exploring the impact of new technologies on young children's numeracy practices.

INTRODUCTION

Young children are being born into a world that is built on digital technology − a world where having competence and the disposition to use mathematics in context is essential. Considering the widespread demand for a numerate citizenry in a digital age, it is essential that young children develop the foundations of digital-numeracies. Throughout this paper, the term, "digital-numeracies" is used as a parallel term to digital-literacies (Lankshear et al., 1997). Thus, "digital-numeracies" are the numeracy practices, behaviours and events which are mediated by new technologies. These technologies comprise technological innovations that have been made possible through digitization, such as digital music players. They also include "old" technologies (e.g., digital television) which have been transformed through the digital signal (Marsh et al., 2005). Thus, research on children's numeracy learning and digital technologies is particularly timely.

Research findings on children's early mathematical growth (e.g., Baroody, Lai, & Mix, in press) together with the growing number of children who spend time in early childhood programs has created an impetus for the creation of policies, curricula and guidelines that support the development of early years care and education (Organisation for Economic Co-operation and Development [OECD] 2006) including mathematical proficiency (Ball, 2004; Clements, Sarama, & Di Biase, 2003; National Association for the Education of Young Children [NAEYC], 2002; National Council for Teachers of Mathematics [NCTM], 2000). Increasingly, digital technologies are impacting on everyday life; hence, children's mathematical proficiency needs to be considered in relation to their learning with and from these technologies. Thus, the purpose of this paper is to examine the current status of peer-reviewed literature pertaining to young children's (birth to eight years) digital-numeracy practices and engagement with new technologies. The outcomes of this review will establish the

scope and adequacy of the literature base and provide directions for future research on digital-numeracies in the early childhood years.

21ST CENTURY CHILDREN, NUMERACY AND TECHNOLOGY

Converging Trends

The past decade has seen the emergence of three understandings related to young children's mathematical learning in the 21st century. First, the early years of life have been highlighted as fundamental to lifelong learning and it has been acknowledged that long-term success in learning and development requires quality experiences during the "early years of promise" (Carnegie Corporation, 1998). Second, the NCTM (2000) has advocated the salient and powerful nature of mathematical proficiency stating that "mathematical competency opens doors to productive futures – a lack of mathematical competencies keeps those doors closed" (p. 5). Contemporary views and theories acclaim that young children are capable of mathematical competencies that are extensive and impressive (Clements & Sarama, in press). Third, the influence of technology on human life in the new millennium has created a world characterized by diverse and energetic communication, vast amounts of information, and rapid change. Technology affects the daily lives of every person, directly or indirectly (Williams, 2002). The coalescence of these three understandings (i.e., early learning, mathematical proficiency, technology) indicates a need to consider what we know about the development of young children's digital numeracies. As a prelude to the examination of the literature young children's digital numeracy practices, a brief overview of 21st children and the relationship between numeracy and technology is presented.

21st Century Children and their Learning

Most children of the western world have access to technology and devices that impact on their lives – whether they be for entertainment (eg., Playstation©) or day-to-day living (e.g., microwave) or in school (e.g., computers). The range of these technological devices is expanding and includes console games, digital music players, video cams, mobile phones, and various digital toys. As the roots of later competence are established long before school age (Bowman, 2001) and findings from neuroscience confirm the importance of the connection between young children's experiences and achievements later in life (Bruer, 1999), it is important to consider how learning occurs from birth to eight in a variety of contexts in addition to school. Opportunities for mathematical experiences and interactions with technology occur before children begin school and in parallel with schooling. Thus, research on the development of digital-numeracies in young children needs to span various ages and learning contexts.

Numeracy and Technology

The skills, knowledge, and abilities needed to participate and succeed in 21st century society are vastly different to those needed in the previous century. The amplified

need for numeracy is a result of the demands of the technologically-oriented age (Her Majesty's Inspectorate, 1998; NCTM, 2000). For example, Steen (1997) argues that modern life is dominated by technology, digital tools and devices, and that "Numeracy is the currency of modern life" (p. xvii). Steen (2001) also credits the rise in quantitative data, numbers, and information to the universal increase in the usage of technology, computers, and the internet. Civil rights leader Robert Moses argues that mathematics has become a humanitarian issue stating, "children who are not quantitatively literate may be doomed to second class economic status in our increasingly technological society" (cited in Schoenfeld, 2002, p. 13). Clearly, numeracy is no longer the fortune of the elite but a requirement for all citizens. Similarly, Malcom (1999) subscribes to the opinion that mathematical achievement in a technological and global society will have a major impact on students' career aspirations, their role in society, and even their sense of personal fulfilment. Thus, the need to understand and to use mathematics and technology is fundamental to 21st century life.

METHOD

ERIC was selected as widely accessible general database that provides free access to more than 1.2 million bibliographic records of educational journal articles and other education-related materials. The PME conference proceedings were selected because PME specialises in the exchange, promotion, and stimulation of scientific information and interdisciplinary research in the field of mathematics education (PME, n.d.). Both investigations spanned the years 2000 to 2005. The aim of the ERIC and PME examinations was to identify the articles that bore reference to young children (birth to eight years), and the development of digital-numeracies or the use of new technologies.

The two research questions were:

1. What was the proportion and scope of articles on technology in the early years published in the ERIC database between 2000 and 2005?
2. What was the proportion and scope of articles on technology in the early years published in the PME proceedings between 2000 and 2005?

The first question was addressed by reporting on one aspect of a larger-scale study that examined the peer-reviewed literature on mathematics education and early childhood during the 6-year time span. The abstracts on the ERIC database on EBSCO host were the data sources for this study. Only articles from peer-reviewed journals were included because they (a) reflect the interests and values of mainstream research communities and (b) have a degree of quality control and credibility through the peer review process. In essence, the research approach consisted of identifying a data set of articles for review from the ERIC database, limiting the data set to include only relevant articles, and ascertaining the representativeness of the literature through a thematic categorization of the articles. Categories were established that best

represented the content theme of the articles. The age cohort investigated was also noted.

The second question was addressed by reviewing the contents of the annual proceedings of the PME conferences between 2000 and 2005. The PME conference proceedings were included because they (a) represent a range of international interdisciplinary research and scientific information in the psychology of mathematics education, and (b) are peer reviewed, and hence of a certain calibre in relation to quality, research significance and interest. It should be noted that some PME papers were indexed in ERIC. The research approach consisted of examining the published PME conference proceedings to identify articles relating to technology and mathematics. The data set was then further investigated to ascertain the theme of the article, and the age cohort it addressed.

RESULTS AND DISCUSSION

What was the proportion and scope of articles on technology in the early years published in the ERIC database between 2000 and 2005?

The ERIC search identified 208 articles relating to young children and mathematics which, due to multiple foci in some articles, resulted in 311 thematically-based codings. Only fourteen of the 311 codings (4.5%) focused on technology. The highest number of articles focused on mathematical concepts (36%) and the lowest number of articles focussed on problem solving (1.3%). The low proportion of articles on technology is surprising and a concern given the importance of technology in 21st century mathematics. Each of the technology articles analysed related to young children's use of computers, software, and information technology and communications during mathematical experiences within a school setting. No articles referred to digital-numeracies in the prior-to-school years. There were also no references found on new technological tools or devices to mathematical learning in the early childhood years.

What was the proportion and scope of articles on technology in the early years published in the PME proceedings between 2000 and 2005?

The total manuscripts published in PME proceedings between 2000 and 2005 was 1857. Of this figure only 145 (7.8%) peer-reviewed items contained a reference to technology and mathematics. Technology papers were represented in a plenary lecture, research forums, discussion groups, working sessions, short orals, poster presentations and research reports (see Table 1). The majority of topics in manuscripts pertaining to mathematics and technology covered topics such as software, interactive whiteboards, CAS-based algebra systems, mathematical learning aided by computers, ICT (i.e., information and communication technologies) environments and tools, pedagogy, graphics calculators, attitudes, and gender issues. The technology-themed papers in the PME proceedings addressed various age cohorts from upper primary school children through to pre-service teachers with one exception on young children. This was a poster presentation by Hoyos (2002) titled

Computer-based mathematical games for preschool children. Thus, over a 6-year period only one PME paper (0.05%) had an early childhood focus.

	PME 24 2000	PME 25 2001	PME 26 2002	PME 27 2003	PME 28 2004	PME 29 2005
Plenary lectures	-	-	-	-	-	1
Research forums	-	1	-	1	-	-
Discussion groups	-	1	-	-	1	1
Working sessions	Not held	1	2	2	-	-
Short oral communications	3	15	7	4	8	6
Poster presentations	1	7	6	7	5	5
Research reports	9	13	10	11	9	8
TOTAL	13	38	25	25	23	21

Table 1: Published presentations with a technology focus in PME proceedings from 2000-2006.

The analyses of ERIC and PME publications that address the early childhood years, mathematics and technology revealed significant limitations with the literature base. Proportionally, only 4.5% of ERIC articles and 0.05% of PME articles focused on this topic over a 6-year period. Additionally, only one PME paper focused specifically on the prior-to-school years, which are recognised as important for life outcomes. Moreover, none of the ERIC or the PME papers focused on new technologies. Given that today's young children are digital natives, that is "native speakers of technology, fluent in the digital language of computers, video games, and the internet" (Prensky, 2001), research is needed on the learning opportunities and demands of the breadth of technological tools and environments.

These outcomes of the review of the ERIC and PME are *not* exceptional but appear to be representative of the orientations of professional groups over time with respect to the emphasis on technology and young children. For example, 10 years ago a *technology-themed* conference by the Mathematics Education Research Group of Australasia [MERGA] (Clarkson, 1986) published 80 manuscripts, of which seven referenced mathematics and technology. However, none of these articles pertained to young children's use of technology. Nearly a decade later, a review of research between 2000 and 2003 by the same professional community (Perry, Anthony &

Diezmann, 2004) revealed an emphasis on technology in a chapter by Goos and Cretchley (2004). This chapter discussed the research on teaching and learning mathematics with computer-based technologies, and the role of computers in student learning. However, as with research published by ERIC and PME between 2000 and 2005, there was scant attention to technology and young children. Only one study on young children and technology use (Lowrie, 2002) was identified in the MERGA review (Perry et al., 2003). Lowrie's work investigated 6-year-old children's capacity to interpret and construct 3D-like images in computer environments. However, no research was reported on children's use of digital technologies in these early school years. Additionally, no research was reported on any type of technology use in the prior-to-school age range.

CONCLUSION

The review of literature published in peer-reviewed journals and PME conference proceedings identified research agendas investigating primary and secondary students', and teachers' engagement with computers, software, and within ICT environments. In the past few decades a shift in perceptions about young children's learning and mathematics in a digital age has been witnessed. However, this shift is not mirrored in the literature. The review revealed a dearth of research on digital-numeracy engagement in the early years and a paucity of research on young children's learning in the prior-to-school years. In our increasingly technological and information-based society, *mathematical proficiency* is necessary for productive participation in life and success in public and private ventures. Hence, research needs to provide adequate guidance on early childhood mathematics education in order to increase the likelihood of children's success and to develop a numerate citizenry. A substantial literature base would inform policy and practice and further validate the essential nature of early childhood mathematics and technology by providing convincing evidence about their plausible effects (Slavin, 2002). Additionally, such research would also contribute to the void of knowledge surrounding the impact of new technologies on the mathematical experiences of young children.

As technology usage and numeracy demands increase in society, it is essential that all participants are considered with special attention given to the gatekeepers of our future – the children. In order to participate and thrive in today's digital age and contribute to tomorrow's future society, individuals need to become digitally-numerate. For example, considerable mathematical knowledge and technological knowledge are required to make informed decisions about the best mobile phone and plan. The ability to make informed decisions about mathematical situations determines whether or not these individuals have first or second class economic status in society. Thus, research on children's numeracy learning and digital technologies is not only timely but necessary. Children are the pioneers of the future – what they learn, how they learn and when they learn has 21st digital-numeracy connotations - research agendas must acknowledge and respond to this actuality if we are to fulfil the responsibility of working towards equity for all.

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