Reflecting on creativity and cognitive challenge: visual representations and mathematics in early childhood – some evidence from research

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What does research tell us about cognitive challenge, creativity, cognition and visual representation, and how can the research inform practice in mathematics in the Foundation Stage?

Considering creativity (briefly):

- Craft and Jeffrey refer to 'practice which fosters creativity' (2004)
- The Curriculum Guidance for the Foundation Stage emphasises that creativity 'begins with curiosity and involves children in exploration and experimentation… they draw upon their imagination and originality. They make decisions, take risks and play with ideas… If they are to be truly creative, children need the freedom to develop their ideas and the support of adults' (DfES 2000: 118)

The relationship between visual representations, levels of involvement and cognitive challenge

- Research conducted in Oxford and published in 1986 (Sylva et al,) identified as 'high levels of cognitive challenge' when the child's activity was: 'novel, creative, imaginative, productive, cognitively complex, involving the combination of several elements… is deeply engrossed' (Sylva *et al*.). Art was found to have almost the highest level of cognitive challenge
- Using the same rating system in a Reception class it was found art achieved the highest level of all activities in which children were engaged (Worthington 1996)
- Laevers focused on 'intrinsically motivated involvement' – one of the key indicators of quality learning outcomes (1993): developed by Pascal and Bertram as the 'Effective Early Learning Project' (EEL) (1997)
- In the *Researching Effective Pedagogy in the Early Years (REPEY) Project*, the researchers found that pre-school children do best when they are engaged in activities that make them think deeply, particularly 'environments that encourage "sustained shared thinking" between adults and children make more cognitive, linguistic and social-behavioural progress' (Siraj-Blatchford, I., Sylva, K. *et al.*, 2002)

Evidence from these research studies highlight a number of key messages for teachers and suggest aspects on which they might focus.

Two of the studies above demonstrated the potential of **deep levels of involvement and high levels of cognitive challenge** through **art**.

Furthermore two of the studies referenced above highlight clear links between activities that lead to both **high levels of involvement** and high quality outcomes for learning. **Sustained, shared thinking** and **high levels of cognitive and linguistic progress are also clearly linked**.

Pedagogy that supports such outcomes are clearly of vital importance to **mathematics** and particularly significant for a curriculum area in which both the spoken and written 'languages' of mathematics are key to understanding.

Study of teachers' perspectives of creativity in mathematics

The work of researchers such as Craft (2002) on the role of creativity in the Early Years; Csikszentmihalyi (1997) on the creative process; research on creative thinking (e.g. Fisher 1990) and approaches such as *philosophy for children* (Lipman1988) have demonstrated the value of creativity in learning.

Since the *Curriculum Guidance for the Foundation Stage* (DfES 2000) emphasises the importance of creativity in children's learning, we were interested to see to what extent this aspect of learning was recognised and supported within mathematics for children in the Foundation Stage. This section draws on research that we have conducted recently with teachers in England, into creativity in mathematics (Carruthers and Worthington 2005b).

In the Foundation stage curriculum document *creativity* is presented almost as a 'subject' and generally promoted as relating to the arts such as dance, music, drawing, painting and stories, in spite of the fact that practitioners are informed that 'young children's learning is not compartmentalised' (DfES: 45). Mathematics is presented largely as 'key skills' to be acquired and knowledge to be understood and although there is recognition of the need for children's experiences of mathematical to be enjoyable (DfES 2000: 70) and meaningful (p.71); the need to promoting deep levels of thinking and creativity are noticeable absent.

We were interested to discover to what extent teachers see mathematics as providing opportunities for creative thinking and ways of working in mathematics. What sort of things had they seen children do in mathematics that they identified as 'creative'? What did they know about any official guidance on teaching early 'written' mathematics? How did their understanding of early childhood development – particularly of the importance of self-initiated play, talk, thinking and mark-making to support children's learning inform their practice?

Data was collected from:

- 231 teachers in three areas of England completed questionnaires, with follow-up telephone interviews with approximately 10% of teachers, to explore responses in greater detail
- Teachers were from maintained nurseries; voluntary pre-schools; private day nurseries; Reception classes; Reception / Y1 classes

Some findings:

- 65% of teachers thought that mathematics was either 'quite' or 'a lot' creative: 29% thought it was 'very' creative
- The majority (over 79%) gave non-specific examples (resources or activities) of children engaged in 'creative' mathematics

Examples of 'creative mathematics'

- Role Play – 12%
- Patterns – 12%
- Construction – 9%
- Shape – 9%
- Art (printing, painting, collage) – 7.5%
- Songs and rhymes – 5.1%
- Sand – 4.6%
- Other (various) – 40.8

- Examples cited suggest that teachers tend to see creativity in mathematics as concerned with specific *resources or activities*, rather than processes

- Teachers were invited to provide specific examples of something they had seen a child do that was creative in mathematics: however, only one teacher out of 231 responded in this way. This may suggest that teachers fail to 'see' mathematics when observing children
- Almost 43% said they were either unsure or confused by the official guidance for teaching early 'written' mathematics – or left this question blank
- Mathematics through self-initiated play, talk and thinking were cited as creative by only 9% of teachers
- Just 5% cited children's mathematical mark-making - *mathematical graphics* (or early 'written' mathematics) as creative

In another study with teachers on the use of children's own written marks and written methods (see Worthington and Carruthers 2003b) teachers told us that they rarely kept examples of children's informal mathematical marks, thereby missing valuable opportunities to inform their understanding of individual children's development. This suggests that children's own marks - particularly when they are made within child-initiated play contexts – are not seen as significant in contributing to the children's developing understanding: children's 'written' mathematics appears to be seen as significant only when it is the outcome of a teacher-directed activity.

We also compared examples of 'creative mathematics' identified by teachers in this study (Carruthers and Worthington 2005b), with examples of children's *mathematical graphics* from our earlier research (Worthington and Carruthers,2003a; Carruthers and Worthington 2005a).

Teachers appear unclear about many of these critical aspects, suggesting that the guidance for practitioners in the Foundation Stage document (and also the guidance from the Numeracy strategy, for reception teachers) both need to provide greater clarity. There is also much for practitioners to consider in respect of pedagogy of early written mathematics.

Recommendations for the Curriculum Guidance for the Foundation Stage:

- Official guidance on **creativity** throughout the curriculum needs to be integrated and much clearer – especially to help practitioners see beyond the resources
- Children's **cognitive development** needs to be given higher priority within the curriculum
- The official guidance on **teaching early 'written' mathematics** to children in the Foundation Stage, needs greater clarity and to be rooted within **evidence-based research**

- Greater prominence need to be given to the importance of ***meaning-making*** for children's **cognitive development** in the Foundation Stage curriculum. The relationship between **play, multi-modal learning** (Kress 1997; Pahl 1999; Pahl and Rowsell 2005), to **visual representations including drawing** (Matthews 1999 and 2003; Anning and Ring 2004); to **other graphical and symbolic languages such as early emergent writing** (Clay, 1975; Hall, 1987) **and mathematical graphics** (Worthington and Carruthers 2003a; Carruthers and Worthington 2005a) needs to be made much clearer.

Recommendations for support for teachers, and for their pedagogy:

- Teachers need support to see that **creativity does not depend on specific resources** or activities, and to recognise **the importance of creativity throughout the curriculum**
- **All forms of visual and multi-modal representation need to be valued by practitioners and given greater prominence** in Foundation Stage settings, for their **potential in supporting children's meaning-making**
- Teachers need help **to recognise mathematics within child-initiated play, talk and representations,** to understand that **children can be highly creative in their mathematical thinking through their own mathematical mark-making** and recognise the value of all forms of visual representations in supporting **high levels of cognitive challenge**
- Teachers need help to understand the huge potential of **children's mathematical graphics** in developing understanding of the abstract written language of mathematics and of written methods of calculations
- Teachers' may need help in recognising children's mathematical explorations and their creative thinking, when they make **observations** (evidenced through their play, talk and representations). This will support teachers so that they can plan to extend children's learning, based on what they have seen, and to **build on what children already know, understand and can do**.

Creativity in Mathematics

Outcomes from the two studies in which we looked at the development of children's own mathematical graphics (Worthington and Carruthers 2003a; Carruthers and Worthington 2005) and children's experiences with written mathematics reported by their teachers (Carruthers and Worthington 2005b), highlight contrasting experiences of early 'written' mathematics for young children. Our findings suggest that a narrow perspective of children as learners is likely to severely limit creativity in

mathematics and may lead to low levels of cognitive challenge for young learners in respect of talk, thinking and particularly of modes of representation: similar concerns about levels of cognitive challenge in mathematics were also raised in another recent study (Adams *et al.* 2004).

In a recent paper we explored the relationship between *art* and mathematical graphics and argue that children's mathematical graphics appear to support deep levels of thinking in ways that are similar to the role of drawing for adult artists and mathematicians (Worthington and Carruthers 2005). The development of children's mathematical graphics also appears to encompass the same range of marks as the development of children's early drawings from infancy that Matthews has identified (1999).

It is interesting to note that whilst children's visual representations such as drawing receive less interest than the currently 'higher profile' curriculum areas of numeracy and literacy, research into children's early symbolic (visual) languages such as emergent writing and mathematical graphics indicate the considerable potential that such approaches hold for young learners. And drawings themselves have considerable value for children's development (Matthews 1999; Anning and Ring 2004).

An additional area for concern is that whilst the Foundation stage curriculum recommends that 'early years experience should build on what children already know and can do' (DfES 2000: 15), this appears to rarely happen with their 'written' mathematics. There is confusion too about the place of *any* written mathematics in the Foundation stage although our evidence is clear: children learn about the abstract written symbolism of mathematics by making connections between their own early mathematical marks and the symbols and calculations to which they are gradually introduced in school. We describe this as a *multi-competent* stage (Worthington and Carruthers 2003) that is similar to a stage in which young children learn a second language (Cook 1992: 16); to the 'third space' identified by Pahl and Rowsell (2005: 66) and to the way in which children 'make sense of continuities and discontinuities' that Anning and Ring identify (2004: 7). These studies points to research findings in areas as diverse as second language learning; literacy; drawings and mathematical graphics highlight to related procedures in their learning, as children link informal and formal and home and school understandings.

Many teachers in our study also felt that 'practical' mathematics should be the exclusive focus in the Foundation stage, although this is not the recommendation of the Foundation stage document. Practical mathematics (e.g. with blocks, sand, water and games) all provide valuable experiences: however in

themselves they are not *directly* related to children's understanding of the abstract *written* language if mathematics. Children learn about written mathematics through using their own written mathematics in ways that are similar in some respects to early writing (evidenced by the numerous studies of emergent writing throughout the past thirty years).

Graphical and symbolic languages such as drawing and mathematical graphics provide rich contexts for children to explore their thinking and allow teachers a window on children's understandings. Such representations also provide a *visual* context of children's thinking that is 'out there', allowing for dialogue between the individual child and an adult; for collaborative discussion and for co-construction of meaning. Visual representations were recognised by Vygotsky as powerful *cultural tools* that support learning within socio-cultural contexts (Wertsch 1985) and as such have an important role in children's developing understanding

Our research shows how children's mathematical graphics can be inventive and joyous, reminding us of the amazing creativity of young children if only teachers have confidence and understanding to support such representations. Mathematical graphics are *inclusive* since children are able to represent their mathematical thinking in ways that they choose and that match their thinking. Mathematical graphics also allow children to explore their thinking in ways that mirror the thinking of artists and mathematicians. Viewing children's representations from a positive perspective provides opportunities for children to explore and make decisions about their own chosen forms and has the power to support deep levels of cognitive challenge, of rich language discussions and high levels of creativity. These processes underpin the recommendations of the curriculum for the Foundation stage in England, yet as our research has shown may not yet have reached many Foundation stage settings and classes.

There is therefore, a very real and as yet largely unrealised potential for developing high levels of cognitive challenge and creativity in mathematics through encouraging children's mathematical graphics.

This short overview of some evidence from research points to a need for teachers to 'listen' to children's voices and to recognise, value and support children's thinking and visual representation in mathematics. Failure to do so will mean that opportunities for creative thinking in mathematics will continue to be limited. This has significant implications for young children's understanding of mathematics.

What are your views on these issues? Is creative thinking in mathematics for young children limited? Do you have any research to share? As ever, please contact Janet Moyles with your response (j.moyles@ntlworld.com)

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