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From astronaut to problem solving: tracing children's symbolic meanings

Maulfry Worthington

Abstract

A semiotic or 'meaning-making' perspective underpins children's symbolic play, enabling them to see that marks, symbols and other graphical representations can mean or 'signify' something. Whilst the 'written' language of mathematics is integral to the subject, research has shown that children find this aspect of mathematics particularly challenging and is a problem that persists.

This chapter traces the thread that links children's symbolic play with later calculations and problem solving, highlighting their creative mathematical processes. This has relevance for mathematics throughout the Foundation stage and Key Stage 1, and has implications for 'written' mathematics in Key Stage 2.

Cameo 1

Nursery – Nathan's astronaut

Figure 11.1 *Nathan's astronaut*

Nathan was busy tucking some pieces of green and purple paper beneath the flap of an envelope and secured it with masking tape (figure 1). He explained that it was '*an astronaut'*, and announcing *'Blast off'* lifted it above his head and moving his arm in an upwards, diagonal trajectory, made a 'whooshing' sound as he announced in an excited voice that it was *'flying to the moon'*. Nathan then showed that by lifting the masking tape, the 'astronaut' could get out of his spacesuit (the envelope)[1].

Cameo 2

Nursery - Isaac takes 'bookings for the campsite'

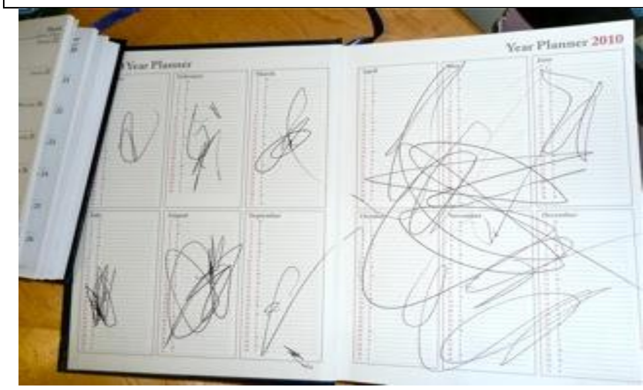

Figure 11.2 *Isaac's bookings book* **Figure 11.3** *Oliver's reservations*

The nursery teacher Emma had set out musical keyboards for some children to play. Several telephones and old diaries had been left nearby and to Emma's surprise, rather than playing the instruments Isaac took a diary and announced he was *'taking bookings for the camp site'.* His friend Oliver immediately responded, and picking up a phone said he'd like to stay for two nights. Isaac replied *'No. I'll put you down for two million nights, but don't worry, it's only £1 a*

[1] Cameos 1, 4 and 5 are used with kind permission of Sage Publications; cameos 2 and 3 are included with kind permission of Open University Press.

night'. He then made marks in his 'booking book' (a diary) and Oliver made his own symbols in another (Photographs 11.2 and 11.3).

Cameo 3

Nursery – 'Look! No chicken!'

Figure 11.4 *Shereen takes orders* **Figure 11.5** *Look! No chicken!*

Shereen was engaged in playing cafés, play that she had initiated. She drew some wavy lines on a notepad, asking her teacher *'I'm writing chocolate bar, what you want? I've got rice, chocolate, chicken?'* Emma replied that she'd have rice and handing Emma a bowl Shereen explained: *'There you go, it's 2, 1, 2'* (referring to the price of a bowl of rice). Soon Shereen returned to see if she wanted anything else to eat, and referring to her notepad asked *'what you want: rice, chocolate, cake and chicken?'* Emma said that she didn't want chicken and Shereen wrote something for 'chicken' and put a cross by it saying *' It says 'x' – no chicken'* (figure 5).

After a while Shereen returned once more to see if Emma wanted anything else and this time Emma said that she would have some chicken. Pointing to the 'x' she had written, Shereen said firmly *'Look! No chicken! You want mushroom?'* and Emma agreed. Shereen added a tick by her drawing of a mushroom, explaining '*Look. A tick, that mean we got some'*, then added, '*you want ice cream? It's 3, 4.'*

Introduction

During the past 2 decades research has revealed how a semiotic perspective through graphicacy supports children's understanding of the abstract symbolic language of mathematics (Carruthers and Worthington, 2006, 2011; DCSF, 2008). Whilst symbolic (pretend) play and calculations might appear unconnected, these elements are inextricably linked through 'semiotics' that is the study of 'meaning making', enabling us to make and communicate our thoughts. We make meanings through a diverse range of signs or 'symbolic' tools' that enable us to perform 'psychological' tasks (Vygotsky, 1978).

Symbolic play and graphicacy

In Vygotsky's view symbolic play (particularly role-play) provides rich contexts for this meaning making. Children have a natural propensity for symbolic play which is seen as 'a leading factor in development' in childhood' (Vygotsky, 1978) and it is valuable in two distinctive and related ways. Firstly children use 'symbolic tools' that help them come to understand how one thing can be used to mean or 'signify' something else, for example, using gestures, actions and speech, or artefacts that they substitute for other things and those they make (such as Nathan's astronaut), (e.g. Kress, 1997; Worthington, 2010a). Secondly, by building on their earliest awareness of relationships between objects in their meaningful play contexts, children come to understand that graphical marks and symbols can also be used to signify something, (Carruthers and Worthington, 2011).

Imagination and symbolic play have been shown to underpin children's writing and drawing (Vygotsky, 1983), research that Luria had begun in 1929: they also have considerable potential for children's understanding of the symbolic language of mathematics (van Oers, 2005; Worthington, 2010a).

Whilst the benefits of play have been well documented, this is no way to suggest that play should be used to ‘prepare’ children for the subjects of school.

In cameo 1, Nathan made personal meanings about astronauts though the materials he used, through using a combination of action and movement, the accompanying sound he made and through his verbal explanations. This example illustrates the complex multi-modal nature of young children’s play and how children synthesize various means to best suit their purposes as they explore, make and communicate complex signs (Kress, 1997; Pahl, 1999). In this instance Nathan combined some elements from his every-day experience (of dressing and undressing), to signify new meanings (an astronaut removing his suit), with his knowledge of technologies and popular culture (e.g. Marsh, 2004; Wohlwend, 2009; Worthington, 2010b). Nathan’s lack of specific visual details in his astronaut was balanced by his actions and words, which were sufficient to ensure that others understood meaning.

Communicating mathematical thinking through graphicacy

Cameos 2 and 3 provide examples of young children making early explorations with marks and symbols, as they attach mathematical meanings to them in ways that made personal sense. Isaac’s ‘booking for the campsite’ show that he knows it is advisable to book before going camping, and that reservations are written down. Isaac’s scribble-marks appear to be *indications* of writing, rather than early written letters. Offering to book “two million nights” and adding *”Don’t worry – it’s only £1 a night”* suggests that he knew that the real figure for one night’s camping would be more than £1.00. Shereen’s “Look! No chicken!” emphasises how rich children’s self-initiated sustained play can be. Shereen’s personal use of symbols provides evidence of how much she already knows about the power of graphical symbols and reveals her flexible use of symbols (Worthington, 2009).

These two cameos highlight what has been described as ‘funds of knowledge’, a term that that refers to children drawing on their rich personal knowledge from their home and community contexts in their learning (Moll *et al.,* 1992) and in their play (Riojas-Cortez, 2001). For example, Shereen drew on her personal knowledge of food – shopping, preparing and eating food as a family and eating out in restaurants and 'take-aways'. Isaac's experiences of camping with his family on many occasions supplied the cultural context for his 'bookings for the campsite' and Oliver was able to join in this play.

Vygotsky recognised the importance of personal relevance, arguing that 'writing should be *meaningful* for children, that an intrinsic need should be aroused in them, and that writing should be incorporated into a task that is *necessary and relevant for life'* (1978: 118, emphasis added) and from a mathematics perspective this should also be so for written maths. Teachers' knowledge of children's home and cultural contexts, coupled with sensitive observations of their play will support increasingly rich play episodes. Cameos 2 and 3 show that in this nursery, (where play and graphicacy are extremely well understood and supported), for these children play often arouses in them an 'intrinsic need' to communicate 'written' aspects of mathematics that are 'relevant for life'. In contrast Gifford (2005) observed that a number of researchers (Munn and Schaffer, 1993; Gifford, 1995; Rogers, 1996) have commented on the distinct lack of observable mathematics in either children's role-play or – with the exception of block play – in wider aspects of their play. Branson and van de Walle suggest that 'It may be that for young children, *number is not automatically a salient dimension of the environment'* (2001: 75, emphasis added). Gifford explains, 'I began to conclude that children's role-play was concerned with the larger themes of life, like love and power, rather than mundane things like the price of potatoes' (2005: 2).

However, since numbers are embedded in children's everyday life, there does not appear to be any mechanism that would enable young children to 'select out' numbers in their play. This is borne out by the numerous examples we have of children exploring aspects of number in their play (e.g. Carruthers and Worthington, 2006, 2011; Worthington, 2010a), and in the DCSF publication *Children Thinking Mathematically* (2009) that we were commissioned to write. The implication of this is that rather than being ‘optional extras’, these dual aspects – making meanings in play and communicating mathematical meanings through graphicacy – need to be understood and valued by adults, and that children will naturally and spontaneously use number in their play where the culture supports their meaning making.

The importance of ‘written’ mathematics

Van Oers argues that one of the core concepts of mathematics ‘is the concept of symbol. More importantly, however, symbols also function as means for regulation of the thinking process. They introduce new ways of organising in the course of thinking’ (2000: 136): Vile refers to the ‘inextricable connection with signs and mathematics. One might even say that mathematics consists entirely of a complex system of signs…’ (1999: 87). Yet we appear to have a long way to go if we are to resolve the difficulties children experience with ‘written’ mathematics that Ginsberg identified in 1977. In 1986 Hughes showed that in contrast to copying numerals without understanding, young children could draw on their own early understandings of symbols, although regretfully this interesting research had little impact on pedagogy. Since that time numerous reports including Ofsted’s have raised concerns about written mathematics including children’s written methods, calculations and problem solving every year since 2002. For example, OfSTED’s 2008 report *Mathematics: Understanding the Score* emphasised:

> The fundamental issue for teachers is how better to develop pupils’ mathematical understanding. Too often, pupils are expected to remember
> methods, rules and facts without grasping the underpinning concepts, making connections with earlier learning and other topics, and making sense of the mathematics so that they can use it independently’. The report raised concerns about ‘pupils’ reliance on formal written methods and a reluctance to use informal mental

methods' emphasizing 'The best teaching gave pupils time to think (HMI: 2008: 5/21).

A recent report on young children's 'achievement' (assessed through the *Foundation Stage Profile*) showed that calculations was recorded as one of two strands with the lowest percentage of children achieving this (DFE, 2010b: 44), exceeded only by writing.

Children's own, informal representations

Terwel *et al.* explain that 'in designing representations, students learn how structuring processes develop … enhancing their capacity to generate new solution processes and to transform a representation according to changes in the situation, facilitating the construction of solutions to relatively new and unfamiliar problems'. Representations also 'play a major role in problem solving' (2009**:** 26-27).

However, the ways in which young children develop their understanding of written mathematics has not been a curricula focus, with the resulting 'passive' activities that Jo Boaler highlights. Boaler argues that it is the way in which mathematics is taught that causes problems, 'Students are forced into a passive relationship with their knowledge – they are taught only to follow rules and not to engage in sense-making, reasoning, or thought, acts that are critical to an effective use of mathematics. This passive approach, that characterises maths teaching in many schools, is highly ineffective' (2009: 36). Boaler acknowledges the huge pressure that teachers are under, but argues that this narrow version of mathematics causes low achievement in England and fails produce good performances in tests (2009).

The evidence from current measures of attainment in England (DFE, 2010), appear to confirm that the same is also true for younger children's experiences of written mathematics when they are 4 years of age. Vellom and Pape argue that 'typical' written mathematical tasks (i.e. those that involve one way of colouring-in, copying or completing) are ‘seen as end results or ‘products’. In contrast ‘in more realistic learning contexts, students may make sense of complex phenomena through their efforts to construct and through the use of graphical representations of these complex systems’ (2000: 125) such as children’s *mathematical graphics*, where *processes* of mathematical thinking are emphasised.

Creativity

Rich episodes of symbolic play and *children’s mathematical graphics* reveal the highly creative processes that support children’s cognitive development and their mathematical thinking (see also Carruthers and Worthington, 2011). However, whilst the *Early Years Foundation Stage (EYFS)* emphasises ‘children’s creativity must be extended by the provision of support for their curiosity, exploration and play… [including] mathematics’, enabling children to ‘explore many *processes*’, and that ‘children express their ideas *through a wide range of types of representation’* (DFES, 2007: 104/105, emphasis added), this is not generally what is understood by ‘creativity’ in education, a term that has become synonymous with the arts rather than wider aspects of learning.

Creativity in mathematics: Foundation and Key Stage 1

In 2000 we conducted a study of teachers and practitioners’ understanding of creativity in mathematics, with those working with children from three-to-eight-years (see Carruthers and Worthington, 2006). The main finding of this that almost all responses referred to specific resources or activities such as ‘role play’, patterns, constructions, shape, art, songs and rhymes and sand as ‘creative’: although children may sometimes explore these resources or activities in creative ways, they are no guarantee of creative learning.

This view of creativity continues to be widely held: for example a recent report on creativity proposes:

> Problem solving reasoning and numeracy are supported as concepts of shape, size, line and area are used to classify and sort objects in the visual arts. Dance provides many opportunities to explore spatial concepts, and sequencing events and objects; for example, creating a pattern on a piece of clay helps children to understand patterns in mathematics (Duffy, 2010: 22).

Regretfully, once again, this appears to confirm the idea that certain activities and resources themselves ensure creativity. Davies and Howe challenge such 'myths about creativity' (2007: 250), arguing that play itself should not be deemed 'creative' and that the almost exclusive association between creativity and the arts needs reconsideration.

'Prescription stifles creativity'[2]

As children move through school, it appears to be common practice to present children with a particular method to use for calculations and to solve problem and whilst the National Strategies propose that 'Mathematics is a creative discipline' (DCSF, 2007: 139), Cowley argues that 'even if learners are given the freedom to solve their own way; if later they are expected to adopt an apparently standard method, their own mathematics is diminished' (2010: 2). He continues, 'mathematics cannot be creative where prescribed methods are used to solve problems' since 'the problem has already been solved … the presentation of the problem without a method of solution is the only road to mathematics as a 'creative discipline'' (2010: 4). These views concur with Boaler's (2009) and the following two cameos focus on children solving problems in which they were 'given the freedom to solve their own way'.

Solving problems – calculating with larger numbers

Cameo 4

Year 2 class – Alison's '99 times table'

[2] Cowley, (2010: 3).

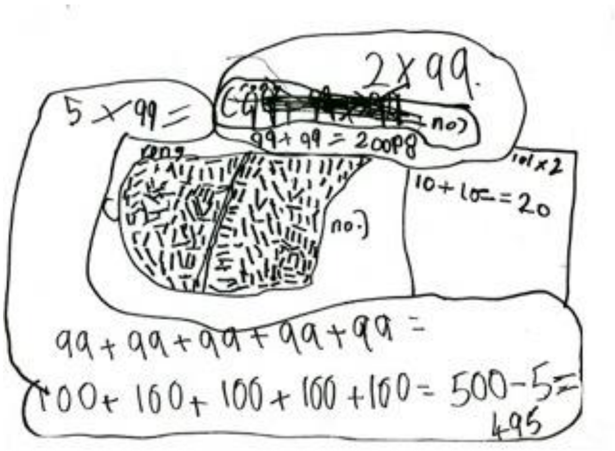

Figure 11.6 ***Alison's '99 times table'***

Alison's class had been learning the 9 and 10 times tables and when asked 'Can you do the *99* times table?' greeted this question with laughter and replies of 'No!' After some discussion about how they might work out the '100 times table' the children felt more confident when their teacher then repeated her challenge to work out the '99 times table'.

At first Alison (figure 7) chose to write '2 x 99', then after some crossing out wrote '99 + 99 = 20098' 'Next she tried using tallies but soon found it difficult to keep track of them and wrote 'wrong' and 'no' next to the boxes she'd drawn around them. This example shows the various strategies Alison tried, including several she abandoned. Alison's teacher joined her, asking her if there was any other ways she could put something down to show 99? Alison hesitated and her teacher suggested she 'think about repeated addition': after beginning with five groups of 99, Alison moved to writing five groups of '100', adding them together and 'rounding up', then subtracting 5 to arrive at her answer.

For Alison, '20098' was a logical way to write '298: children often write numbers above one hundred in this way as it appears logical to them and her crossings out shows genuine 'working out' in progress. The teacher's suggestion that Alison might think about repeated addition appeared to be a 'turning point, as she seemed immediately to make the connection between counting out '99' five times, and using a more efficient and less error-prone method in which she had confidence.

Cameo 4

Year 3 / 4 class: Miles and the nectarines

Figure 11.7 – *Miles, calculating packs of nectarines*

Miles's class was about to go on a residential trip and had planned a picnic to break the journey. Their teacher brought in a pack of 3 nectarines and asked if the children could help work out how many packs she would need to buy, so that each of the 26 children in the class could have a nectarine.

Miles reached for a piece of paper and placing it in front of him in 'portrait' format, drew a line across the width of the page. The way in which he had orientated his paper caused an initial problem since he soon discovered that he would run out of space on his line to make sufficient jumps of '3'. Using a highly adaptive strategy, Miles twice made jumps of '6' (doubling the 3) enabling him to resolve this problem.

In their previous classes these children had been fortunate to have had rich experiences of play, and to develop and build on their earlier understandings of the abstract symbolic language of mathematics. They were confident in solving problems in their own, informal ways through their *mathematical graphics* and by year 2 sometimes integrated some 'informal' taught methods by choice, when they felt they would be of use. In the National Strategies, these informal 'taught' methods include the valuable 'empty number line' and rounding up. In addition to the standard symbols such as ‘+’ and ‘x’, both the empty number line and ‘rounding up and subtracting’ are symbolic tools and add to those they already have at their disposal.

Processes of mathematics

Thinking and communicating mathematically are significant aspects of early ‘written’ mathematics (Carruthers and Worthington, 2008), yet they have largely been overlooked in curricula documents. In the EYFS (DFES, 2007), ‘communication’, ‘thinking’ and ‘language’ (with the exception of mathematical vocabulary) are notable by their absence in the *problem solving, reasoning and numeracy* section of the document. This is in direct contrast to *communication, language and literacy*, which has dedicated sections entitled ‘language for thinking’ and ‘language for communication’, and although ‘using and applying mathematics’ (DCSF: 2006) is emphasised for mathematics in the primary school, OfSTED’s repeated concerns show that children may not always have sufficient opportunities they need to ‘use and apply’ mathematics in their own ways.

The cameos of mathematics in this chapter show the creative *processes* of learning that children used. Cameos 2 and 3 relate directly to *Foundation Stage Profile* (FSP) point 8 *‘Uses developing mathematical ideas to solve practical problems’.* The *Williams Maths Review* (DCSF, 2008) raised particular concerns about this aspect of achievement and the low levels of attainment in ‘calculations’ (DFE, 2010b) are likely to be related to this. FSP point 8 in the EYFS relates closely to the various strands of ‘*Using and applying mathematics’* in the National Curriculum (DCSF, 2006) and includes:

Solving problems

Representing – analyse, record, do, check, confirm
Enquiring – plan, decide, organise, interpret, reason, justify
Reasoning – create, deduce, apply, explore, predict, hypothesise, test
Communicate – explain methods and solutions, choices, decisions’

Cameos 4 and 5 provide evidence of many aspects of *using and applying mathematics*, revealing the thread that runs from Nathan's astronaut to children attaching mathematical meanings to marks as Isaac and Oliver did, and later to calculate and solve problems with larger numbers. They emphasise the continuing importance of *processes* of learning mathematics, throughout the Foundation stage and the Primary school.

Conclusion

Not only does mathematics matter but, so too, do play and graphicacy. Soler and Miller (2003) raise concerns about 'top-down pressures from statutory subject-based curricula' for both school and pre-school aged children, which have prompted 'ongoing struggles to incorporate traditional early years ideologies into recommended pedagogy' (Brooker and Edwards, 2010: 43). However, Brooker and Edwards argue that whilst teachers have many tensions to deal with, 'Ultimately, the 'struggle' described by Soler and Miller (2003) is not simply between different theories of learning but between different views of children'. They suggest that the most positive view of learners is to respect children as 'competent individuals who are capable of making meaning from their experience of the world, in collaboration with others and with the support of cultural tools' (2010: 44). Such views also require a shift away from seeing children's mathematics as full of 'mistakes', and to view and assess their emerging understandings from a positive perspective.

The authors of the *Williams Maths Review* emphasise that the 'United Kingdom is still one of the few advanced nations where it is socially acceptable – fashionable, even – to profess an inability to cope with the subject' (DSCF, 2008: 3). The Review's final report acknowledges the significance of *children's mathematical graphics* in supporting their understanding of the abstract symbolic language of mathematics. 'However,' diSessa *et al.* note, 'how rare it is to find instruction that trusts students to create their own representations' (1991: 156). This view is further reflected in a recent paper by Terwel *et al.* who propose that ‘Although there have been positive changes in the past [two] decades, we believe that today, diSessa’s statement holds true for many classroom practices’ (2009: 28-29).

For too many children, when they move into school at the too-early age of four-years (in England), the ‘written’ mathematics they are given often holds little meaning and fails to connect with their own understandings. Yet our accumulated research findings and recent empirical evidence from an increasing number of teachers and practitioners (Carruthers and Worthington, 2011) show that young children will often readily make and communicate their mathematical meanings in play, and that this underpins their understanding of ‘written’ maths. Brooker and Edwards ask ‘in the debate’ about play and subject teaching, ‘Where are the children, and what do they make of their experiences?’ (2010: 44). Our argument is that by focusing on children’s symbolic play and their *mathematical graphics* children will be central in their learning cultures and in this debate.

Whether teaching in the Foundation Stage or in the primary school, it is hoped that the issues raised in this chapter will provoke critical reflection and an increased focus on children’s mathematics, and will contribute to greater continuity for children’s experiences of mathematics throughout the birth- to 11-years age range.

Questions to set you thinking

1. To what extent do teachers’ observations throughout the Foundation Stage inform adults about individual children’s interests and meaning making?
2. How do teachers in school build on and support children’s meanings, thinking and graphicacy?
3. To what extent are the *processes* of children’s ‘written’ maths recognised and understood, from Foundation stage to KS1, and through KS2?

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