University of Southampton

Doctoral Programme in Educational Psychology

Title: Numicon: A mutli-sensory approach to supporting the development of arithmetical cognition

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Case Introduction and Background Information

Referral Question and Focus of Casework

Clare (not her real name), a year 4 pupil, was identified to the EP service due to concerns held by school regarding her low attainment and poor progress in learning. Specifically, a lack of progress within numeracy was emphasised. Initial consultations also highlighted parental anxieties regarding Clare's academic self-confidence. My role was negotiated as working to gain an understanding of Clare's learning profile (comprising areas of relative strength and weakness), to explore her personal experiences and outlook upon school and to guide the school in decisions relating to appropriate support strategies. The priority focus of this work was clarified as identifying effective ways of supporting Clare to progress and achieve within school and specifically to help facilitate progress with her numeracy skills. Clare's parents were keen to play an active role in assisting any interventions within the home environment.

Existing Provision

Prior to EP involvement Clare had received a relatively high level of support with her learning within school over the past academic year. This comprised specialist wave 3 interventions in both Numeracy ('Primary National Strategy Maths Gap Pack', DCSF, 2010a) and Literacy ('Sound Foundations', Burkard and Burkard, 2010). Clare worked within a small table group (N= approx. 4/5) and was frequently supported by the class' Learning Support Assistant (LSA) for the majority of tasks. No other external services were identified to be working with Clare.

Equiry Method and Information Gathered

A combination of methods was used to gain information and explore Clare's case further. These comprised a series of observations, consultations with parents, staff and directly with Clare), and, use of the British Ability Scales, Second edition (BAS:II, Elliot, 1993).

Clare presented as a generally happy, healthy and polite child within school, with high attendance and who did not cause behavioural problems. Clare reported that she liked school, particularly maths (as she could work in a small group), disliked literacy tasks and found learning difficult. Home further reported that Clare always appeared to want to achieve, trying hard at her work, but often failed to reach the levels of others around her. Upon entry to key-stage 2 (the start of Clare's current academic year) her teacher assessed Numeracy score was at P-level 7, with her Literacy scores on level 1B of the National Curriculum. Both of Clare's older siblings had also experienced difficulties with their learning and had responded well to individualised interventions within mainstream settings. It was emphasised that Clare was frequently told to try her best and was not compared to her peers on performance. Regular home learning activities included supported reading with parents and siblings, alongside 'playing schools' (including drawling, writing and sums). Clare frequently required assistance in these tasks and disliked working alone, contributing to her mother's concerns over her academic self-confidence levels. However, she was also said to initiate them and appeared motivated to get to the end (irrespective of the quality/correctness of the work).

Observations of Clare within small group Numeracy work showed her to choose the most straight forward sums. Having written the sum as neatly as possible (in large print), Clare looked to others (both LSA and peers) for cues or direct support for the next step. Clare extended this visually based strategy by copying other's answers during independent work (assuming her own

work to be faulty and others to be correct). An extreme example of this was observed during a whole class Numeracy activity. The class were seated on the floor and provided with a board each to work sums out on independently. Comparatively, Clare positioned herself on a chair enabling her to copy the work of those around her without the teacher noticing. Clare was able to raise her hand to volunteer answers and enjoyed receiving praise for getting them correct. However, she became confused if questioned further, clearly having not understood the concepts and/or processes involved. Clare's use of such strategies (minimising her effortful involvement in learning and ensuring 'success') were only noticeable through direct observation.

The 'British Ability Scales: Second Edition' (BAS-II) cognitive assessment was used to explore Clare's cognitive profile and question why she used such strategies. Clare's General Conceptual Ability (GCA), composite and cluster scores placed her in the lowest percentiles (1-2), with no significant differences found between or within cluster scores, or in comparison to the GCA score. However, Clare's scores upon the achievement scales were significantly higher that her GCA. Although these scores remained well below the mean, they showed a level of over-performance that suggested that Clare was learning despite the difficulties she experiences. Analyses of the subscales highlighted that Clare's scores within the diagnostic scales, focusing primarily upon storage, search and retrieval processes (including visual and auditory working memory and associative processes) showed some relative strengths. Further, evidence of dependence upon inappropriate visual strategies was shown during the assessment, including looking to the assessor for clues or confirmation, unsuccessful use of finger counting to conserve number, and using visual stimuli from the question sheet to guide guessed answers (e.g. largest number, closest/most frequent shape). On one test Clare simply named accidentally displayed items back to the assessor. Once this strategy was recognised and the stimuli moved, Clare's

performance significantly decreased.

Following this exploration of the problem dimensions, it was conceptualised that the difficulties Clare experienced across all areas of her learning had a cognitive basis, exacerbated by an over-reliance upon existing visually based strategies, social support and a faulty understanding of success and failure within learning.

Recommendations and Intervention

The following within class strategies were recommended:

- Use written and verbal 'scaffolding/signposting' to support Clare's independent work.
- Avoid overload by breaking tasks and instructions into achievable parts, provided sequentially upon completion to help Clare develop organisational skills and raise self-esteem.
- Provide instruction in combined visual and verbal formats where possible.
- Encourage Clare to verbalise her thinking to ensure learning.
- Provide frequent positive feedback, praising effort over outcome.

Further to above, it was recommended that Clare continued to follow the existing wave 3 Literacy programme ('Sound Foundations', Burkard and Burkard, 2010). However, it was recommended that her Wave 3 numeracy intervention was changed to the Numicon system to be completed for 15-20 minutes each morning. Further, materials and guidance were offered for parents use with Clare in home learning tasks. It was felt that the concrete materials involved in this approach would build upon Clare's apparent visual preference, help solidify her

understanding and use of the abstract numerical system and help refocus her conceptualisation of success within learning to developing understanding rather than task completion.

Outcomes

Following one term's input Clare's teacher assessed scores showed progress. Her Literacy scores had improved by between 1 sublevel (writing = 1A) and 2 sublevels (reading and speaking = 2C). Clare's Numeracy scores had risen by more than a whole level to 1B (a sublevel, P8 to 1C is considered as a whole level of change). Comparison between these scores and the progression guidance published by the (DCSF, 2010b) showed Clare was progressing in line or above expectations based upon her starting point. Utilising the progression target chart it was possible to see that if Clare continued at her current rate of progress she would end KS-2 in the middle to upper quartile for those starting with her scores and could hope to make the targeted 2 levels of progress with appropriate support. School staff also reported an increase in Clare's efforts in solving her own tasks rather than copying the answers of others. This was interpreted as an indication of an increase in both Clare's arithmetic skills and her academic self-confidence.

At the review Clare's progress was not assessed through any element of the BAS-II. As less than 6 months had passed use of this tool was deemed inappropriate. However, it was proposed that the achievement scale may be repeated towards the end of the academic year to triangulate teacher assessed measures of her progress.

Account of literature related to the case presented

Arithmetic has been identified as a common source of difficulty, with reports that 15-20% of young people will struggle with learning within this area and experience associated negative

outcomes in practical, educational and/or employment elements of their lives (‘Every Child a Chance Trust, 2008). Further research findings have suggested that approximately 6% of primary aged children will experience severe difficulties and require addition assistance through specialist intervention to support their mathematical development (Gross, 2007). Dowker and Sigley (2010) report that this is a common picture worldwide, with this figure similar to those produced from research conducted in other countries such as Germany and Israel. Some evidence has pointed to co-morbidity in difficulties with literacy and numeracy, specifically with dual diagnoses of dyslexia and dyscalculia reaching as high as 60% in some studies (Yeo, 2004). However, recent research conducted in the UK exploring grades achieved at the end of key-stage 2 (SATS in 2005) has suggested that a higher proportion of pupils experience difficulties in one area rather than in both (Gross, 2007). Importantly, these findings do not discount that a significant amount of pupils experience difficulties in multiple areas, rather it highlights that these severe problems may not be related and may not necessarily be experienced in combination.

Despite this, much less research into the development of mathematical skills has historically been conducted than in other areas such as language and literacy (Dowker and Sigley, 2010). However, in more recent times, greater attention has been paid to this area within both the fields of research and educational policy and practice within the UK (Williams, 2008). Current leading conceptualisations suggest that mathematical cognitive ability comprises multiple skill components including counting, memory for arithmetical facts, understanding of concepts and the following of procedures (Dowker, 2009). Cognitive developmental research utilising contemporary neuro-scientific methodologies has strongly suggested that these areas (constructed of narrower subcomponents), though often correlated, are independent of each other

making distinct areas of strength and/or weakness possible for both typically developing children and those with identified arithmetic difficulties (Dowker, 2005; Butterworth, 2005). This realisation is essential to dispelling the myth that people are either 'good at -' or 'bad at maths'. Importantly, such research findings indicate that arithmetic components do not exist in a strict hierarchy (Dowker and Sigley, 2010). Within education this could present as a pupil who is able to solve a word-based problem (a relatively difficult task), but may struggle with the counting word sequence (a relatively easier task). This differs greatly from the hierarchical nature of language development and may mask pupil's areas of difficulty until compensatory skills become unsuccessful.

The development of mathematical cognition remains an important area of intervention. Analyses upon nation-wide standardised assessments (key stage 2 SAT scores) between 1996 and 2007 have shown improvements in attainment following the introduction of the National Numeracy Strategy (Williams, 2008). However, other findings suggest the gap between the highest and lowest achieving children is increasing (Dowker, 2009). This highlights an important role for Educational Psychologists (EPs) in helping guide the choice and use of support measures and direct interventions aimed to facilitate the development of arithmetic cognition. It is important to ensure that, as the scientific practitioners Regan and Woods (2000) assert EPs to be, our recommendations and the strategies we support have both firm theoretical underpinnings and a strong evidence base of its effective use in practice. Herein, the Numicon system (Atkinson, Tacon and Wing, 1999) will be explored as a possible approach to supporting

Numicon: Background and theoretical underpinnings

The Numicon system is a multi-sensory approach to developing understanding of abstract

number ideas (Wind and Tacon, 2007). As such it builds upon the visual approaches of Stern (1949) and the use of concrete representations of number such as coloured rods (Cuisinaire and Gattegno, 1957) to develop arithmetic capability (Nye, Buckley and Bird, 2007). Many children have been identified to struggle with their mathematical understanding when the primary curriculum moves away from concrete and visual activities, becoming more abstract in nature (NCTM, 2000). The Numicon system, developed by professionals with over 85 years of combined experience of teaching Mathematics to young people in a variety of educational settings, utilises physical representations of number that vary by shape, size, colour and pattern to help bridge the gap between concrete and abstract understandings. It is designed for use with children of all ages and abilities (Wing and Tacon, 2007).

In an evaluation of the 'Numicon system as a tool for teaching number skills to children with Down syndrome', Nye, Buckley and Bird (2005) underscore its ability to support young people to develop mental imagery for numbers by providing concrete visual representations of whole numbers as a key strength. Development of strong visual and linguistic representations of abstract concepts has been linked with the development of effective internal representation systems related to counting, processing, recalling and understanding information (Thomas, Mulligan and Goldin, 2002). This strongly links to the development of mental arithmetic skills, an essential skill within the current Mathematics National Curriculum (Wing and Tacon, 2007). Further, Nye, Buckley and Bird (2005) highlight that the Numicon materials, encompassing inter-connectable plastic shapes (representing whole numbers from 1-10), coloured pegs (representing units) and base boards enable young people to explore the relationships between numbers in multiple modalities simultaneously. Each of the plastic Numicon shapes represents a number between 1-10, based upon a simple square pattern following a 'one more principle' (i.e.

each shape has one more square to it and differs by colour). The apparatus enables pupils to simultaneously learn visually and kinaesthetically by physically doing sums and seeing the effects of what they do (Wing and Tacon, 2007). Together with the systems flexibility to incorporate everyday objects, the active role of the learner in manipulating the combinable Numicon materials help to make maths 'real'. It has been suggested that this supports development and retention of mathematical understanding and encourages generalisation of conceptual learning (Willis and Johnson, 2001; Wing and Tacon, 2007).

Further, Willis and Johnson (2001) assert that successful teaching of arithmetical cognition is dependent upon appreciation and application of Gardener's theory of multiple intelligences (1993) to ensure that different learning styles are catered for. The multi-modal nature of the Numicon approach follows this theoretical standpoint and, by differing from the teaching approaches of classroom, may appeal to those with different learning styles. All of the activities within the Numicon approach, which follow a game-like presentation style are closely linked to the National Numeracy Strategy and appropriate sections of the National Curriculum (Nye, Buckley and Bid, 2005; Wing and Tacon, 2007). Further, as pupils progress past the initial foundation teaching stage, Numicon can be used as a flexible tool in individualised interventions differing by intensity (frequency and time), by target areas, and by mode of use (visually, kinaesthetically, as a prompt etc.). Hasler (2008) maintains that for interventions to be effective, this level of personalisation is required. In light of this, as part of 'The National Strategies' Dowker (2009) has recommended Numicon as a suitable wave 3 intervention for use in Primary schools throughout the UK.

The Use of Numicon within Schools

A comprehensive review of the use and educational outcomes of the Numicon system and been published by Wing and Tacon (2007). The initial research study involved in system's development within an infant school in the Brighton Local Authority (LA) reported significant improvements in key stage 1 results for the 1998 and 1999 cohorts taught using the Numicon materials when compared to the previous 1997 cohort. Further, a follow up study showed that the Numicon cohorts achieved better results at the end of key stage 2 (in terms of percentage of pupils gaining a level 4, improving from 56% of the 1997(2001) cohort, to 75% of the 1999(2003) cohort). However, as the Numicon system was not used within the key stage 2 teaching of these cohorts, any interpretation of the results as showing lasting benefits of the system should be tentative as causality cannot be assumed. In light of the success of these findings and following an independent small scale research project, Devonshire LA Primary Maths Team recommended the use of Numicon to support learning in all of their primary schools (Wing and Tacon, 2007). Further LA have conducted research into the use of Numicon as a wave 3 intervention to support the learning of children failing to succeed with mathematics within schools, including Leeds, Cambridge, Wiltshire, Portsmouth and Brighton and Hove. Results from the research project in Cambridge are yet to be published, where Numicon has been trialled within 8 schools (Wing and Tacon, 2007). Within this project pupils were provided with intensive one-to-one Numicon sessions for 25minutes, 3-5 times a week for a term and a half. Pre-publication reports have suggested that progress of up to a whole national curriculum level (1C-2C) have been achieved by some children, with significant gains for those at lowest levels progressing from P7/8 to 1C/1B (Wing and Tacon, 2007).

Much of this research has been based upon teacher assessed progress or nationally

standardised end of key-stage scores. However, studies into the suitability of the Numicon approach to teaching those with Down Syndrome have employed more robust standardised psychological assessment tools, such as the BAS:II (Elliot, 1996). A pilot study conducted in Wiltshire LA (Ewan and Mair, 2002) assessed the impact of the Numicon approach on the performance of 11 children with Down syndrome. Participants (aged between 8-11 years, studying in key-stage 2 and 3 in a combination of mainstream and specialist settings) received 10-15minute intensive one-to-one teaching using the Numicon materials for 5 months. Participant mathematical performance was assessed pre- and post- intervention by the BAS:II Number Skills achievement subscale. Quantitative results indicated a mean gain of 6.9months on the post-intervention age equivalent measure of mathematical performance. Ewan and Mair (2002) suggested that this progress was much higher than would be normally expected, with regular progress for the participants being less than a month per month. Further, qualitative feedback suggested that use of the Numicon materials helped to identify and address unknown conceptual gaps in mathematical knowledge (such as big and small). These results match those of parental feedback that report vast improvements in attainment, understanding and attitude towards mathematical learning (Horner, 2002). However, the lack of a comparison control group questions whether the Numicon system can be considered responsible for the improvements in performance reported.

More recently, a one-year in-depth evaluation of the suitability of Numicon as a teaching tool for children with Down Syndrome has been conducted in Portsmouth (Nye, Buckley and Bird, 2005). As with the Wiltshire project, participants (numbering 16) were drawn from both mainstream and specialist settings and were given 10-15minutes of one-to-one Numicon activities per day for the entire academic year. Pre- and post-intervention measures of

mathematical performance using the Number Skills subscale of the BAS:II (Elliot, 1996) were compared. A control group of developmentally comparative peers who had not received input using the Numicon materials was constructed through the retrospective use of local data gathered from longitudinal study into speech and language skills by Byrne, MacDonald and Buckley (2002). Statistical analyses showed the groups to be well matched, with no significant differences in chronological age, pre-intervention BAS:II number scale raw or age equivalent scores, or in the time gap between pre- and post-intervention measurements. Results indicated that the Numicon group scored marginally higher on the post intervention measure, reporting an average gain of 5.83months in comparison to 5months for the control group. However, detailed analyses of the data showed the result to be statistically non-significant (Nye, Buckley and Bird, 2005). That no clear knowledge was available regarding the educational experiences within mathematics of the control group highlights a distinct question of the validity of this comparison. Further, that 5 of the 16 participants had previous experience of the Numicon materials may too have mislead the results of the study.

Appraisal of literature to the case process

I feel that several elements of the literature I have reviewed above have been influential to the case process. Primarily this has been in extending my own understanding of young people's mathematical development but has also impacted upon the information I shared with others involved in the case and my conceptualisation of Clare's difficulties and corresponding recommendations.

From early in the casework process it was apparent that Clare was struggling with both her Numeracy and Literacy skills. However, I felt strongly that these, though co-morbid, were not

solely functional expressions of the same problem. Her difficulties with literacy appeared to be related to the process of writing and decoding, rather than we conceptual understanding, which appeared to be the basis of her Numeracy difficulties. Gross' (2007) assertion that difficulties could co-exist independently was helpful in leading me to investigate these difficulties separately and identify suitable support mechanisms. Further, the conceptualisation of arithmetical cognition as comprising distinct interrelated but independent non-hierarchical components was essential to my understanding of Clare's difficulties and sharing my explanation of these with both parents and school staff (Dowker, 2009).

Clare's difficulties with the move of class based maths activities away from concrete visual representations to rely on more internalised abstract understandings of number clearly mirrored patterns suggested in the research (e.g. NCTM, 2000). Clare clearly reflected the example of a child who would struggle with seemingly simple tasks, whilst able to complete apparently more complex ones. Although she identified Maths as a subject she enjoyed, Clare also felt it was something she was not good at. Using the evidence presented by Butterworth (2005) and Dowker (2005) I was able to positively challenge this perspective and discuss areas of relative strength with Clare. This was an important element in beginning to re-focus Clare's lack of academic self-confidence reported by her mother.

Prior to beginning the case process, I already strongly agreed with the assertions within the literature that recommendations and interventions need to be personalised to be effective (Hasler, 2008; Dowker, 2009). However, Willis and Johnson's (2001) suggestions that a person's style of learning and potential preference for a specific modality of presentation should be considered in line with Gardener's (1993) theory of multiple intelligences when planning interventions was a 'light-bulb moment' for me. This strongly guided my recommendation for dropping the

existing wave 3 intervention in favour of the introduction of the Numicon programme, which matched Clare's apparent preference for visually based strategies. The numerous references to the important impact such multi-sensory approaches may have upon developing strong internal representations of arithmetic concepts also guided this choice (Thomas, Mulligan and Goldin, 2002; Nye, Buckley and Bird, 2005; Wing and Tacon, 2007). I also found Wing and Tacon's (2007) explanation of the manner by which Numicon could facilitate Clare to actively 'do' and 'see' maths in real terms and their use of the term 'mental imagery' highly useful when discussing this area will school staff and parents.

Comparatively, I found some of the research evidence upon the effective use of Numicon in practice disappointing. On one hand the volume of LAs researching and implementing the approach, alongside the recognition within Dowker's (2009) national recommendations, facilitated parent and school's choice to invest time, effort and funds into the Numicon intervention. However, under closer analysis, the strength of the evidence base was not as robust as I had first understood. I feel that this in part may be due to the methodologies of research conducted to date, rather than short comings of the approach itself. Further, the inclusion of the two studies based upon children with Down syndrome may be interpreted as an inappropriate reference group. However, the relative strength of effective use of visual imagery and preference for multi-sensory learning approaches reported for this group lead to my drawing of similarities to Clare's case. Following this, I remain confident that Numicon was and is an appropriate approach to support Clare's progress, as evidenced by her own development.

Reflective evaluation and implications for future practice

Following this process several key points of learning will directly impact on my future practice

as an EP. Other cases involving numeracy difficulties will be informed by my adoption of Dowker's (2009) conceptualisation of the development and structure of arithmetical cognition. Further, my developed understanding that all presenting difficulties do not have to have the same source and may be independent of each other will guide my exploration of problem dimensions. Reflecting Willis and Johnson (2001), a key implication for my future practice is that I will consider the focus child's learning style and potential preferences toward specific modes of presentation when considering recommendations and outcomes of my involvement in casework. In future cases I will consider Numicon as possible approach for those experiencing difficulties with mathematics where conventional teaching approaches are not leading to progress. Further, I will bear-in-mind Numicon's potential value in identifying and addressing conceptual gaps as reported in research findings above. I will also keep look for contemporary research findings based upon more robust designs to add weight to Numicon's validity as effective intervention.

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