Understanding and addressing significant mathematical difficulties

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Across schools in the United Kingdom (UK), it is common for teachers to identify children as having significant difficulties with mathematics. The authors' experiences in schools suggest that, despite interventions, these children continue to have significant mathematical difficulties. Currently there is little research and a lack of agreement across literature as to the aspects of mathematics that children find difficult and the characteristics of these children. In this paper, the authors provide a preliminary review of the literature in this field and propose a study in UK primary schools to address the gaps identified. The proposed study aims to investigate: (i) the characteristics of children who are identified as having significant mathematical difficulties; (ii) the mathematical profiles of these children; and (iii) different perspectives about the nature of a child's number difficulties. With a clearer understanding of these children, we can suggest more appropriate ways to support their progress.

Keywords: Number difficulties; characteristics; primary mathematics.

Research context

Approximately 6% of primary school children show persistently poor mathematics achievement (Shalev, 2007), which implies that there are one or two children with significant mathematics difficulties in each class across mainstream primary schools. However, although this is a significant proportion of the mainstream school population, the vast majority of the research in this field is led by and focuses on special education rather than on mathematics education (Karp, 2013). It may be argued that although special education researchers are experts at working with significantly under-achieving populations, most are not experts in mathematics and therefore there are aspects of mathematics teaching and learning that they may not fully appreciate. Therefore more research into the mathematics learning of this population needs to be undertaken by mathematics education researchers.

Current recommendations from neuroscience and psychology point away 'from a modular and single deficit view towards a dynamic, process–oriented and multiple deficit view' (Kaufmann, 2008, p.167). This identifies the need to consider children with mathematical difficulties as individuals with different background characteristics and mathematical profiles, due to complex and interrelated causes, who show a persistent lack of progress.

Research proposal

To understand significant mathematical difficulties in mainstream schools, individual children without other Special Educational Needs and Disability (SEND) need to be considered as they may have different significant weaknesses in one or more aspects of mathematics that may be remedied by targeted intervention (Dowker & Sigley,

2010). In light of this, the authors propose to work in mainstream schools with children who have significant mathematical difficulties without other SEND, to better understand the characteristics of these children, their profile of mathematical understanding, and the different perspectives on their mathematical difficulties. The authors plan to focus their investigation on social rather than medical models and adopt a case study methodology to incorporate both positivistic approaches to identifying possible common 'characteristics of children' and 'profiles of mathematical difficulties and strengths' as well as interpretivist approaches by considering multiple perspectives (Mack, 2010). To detail this further, the remainder of this paper reviews the literature and sets out research proposals in the following sections: (i) defining significant mathematical difficulties; (ii) characteristics of children with significant mathematical difficulties; (iii) profile of their mathematical understanding; and (iv) different perspectives on children with significant mathematical difficulties.

Defining significant mathematical difficulties

A recent meta-analysis of the research in this field found no consensus on the operational definition of significant difficulties in mathematics nor on the terms used to categorise it (Lewis & Fisher, 2016). Instead, a variety of terms, each with its own operational definition, were found to have been used in the literature to mean similar things, including mathematical learning disabilities, math disability, number difficulties, dyscalculia and low achieving.

Similarly, there is no agreement in how to identify children with significant difficulties in mathematics (Thouless, 2014). While some researchers propose that number difficulties are of neurological or cognitive origins (Butterworth & Laurillard, 2010), often children are identified based on behavioural data such as performance on standardised tests or recommendation by schools. In standardised tests, cut-off criteria range from the 10th to the 45th percentile (Mazzocco, 2007). One drawback of those that propose a 35% cut-off is that this includes groups of children with different cognitive characteristics, growth rates and profiles: for example, Mazzocco (2007) found that children with a neurologically based disorder related to mathematics have standardised test performance below the 10^{th} percentile, whereas children with performance between the 11^{th} and the 30^{th} percentiles are presumed to have mathematics difficulties unrelated to a biological origin. A more recent study favours a 10th percentile cut-off (Mazzocco, Murphy, Brown, Rinne, & Herold, 2013) for identifying children with significant mathematical difficulties. Furthermore, about a quarter of the studies examined by Lewis & Fisher (2016) maintain that the low achievement has to have persisted for two years or more, and rely on multiple assessments to demonstrate significant difficulties.

Drawing on the literature and informed by case studies, the proposed research project aims to present a refined definition of significant mathematical difficulties in terms of the aspects of mathematics that are impacted and how the children are identified.

Research proposal

For the proposed research, in order to consider the breadth of mathematics topics, the authors will adopt 'significant mathematical difficulties' as the working term. It is also proposed that, initially, the current working criteria consider children with significant mathematical difficulties as those who are persistently (for two or more

years) working below national expectations (by one or more years) against the current curriculum.

As the current working criteria are not without limitations, it is expected that they may evolve over time to also consider children who are: (i) persistently (two or more years) achieving significantly lower attainment in mathematics compared to their attainment in literacy, regardless of their absolute performance in mathematics; (ii) persistently making no progress (two or more years) in mathematics, regardless of their absolute attainment in mathematics; or (iii) identified by the school as having significant mathematical difficulties without other SEND. In the latter case, attainment against current curriculum and performance against standardised tests would also be used to justify identification and provide comparisons across schools.

Characteristics of children with significant mathematical difficulties

Lewis and Fisher's (2016) meta-analysis found that currently there is little research on the demographic characteristics of the children with number difficulties, with most studies considering gender differences but not Socio Economic Status (SES), race or language fluency. They also report that: (i) although 75% of studies considered gender, no significant difference between gender groups was found; (ii) similarly, although 17% of studies considered race, most reported no significant difference between groups; (iii) however, of the 12% of studies that considered SES, a quarter reported a significant difference between SES groups, with more Moderate Learning Difficulties (MLD) identified among children from lower SES groups; and (iv) language fluency was considered in 27% studies with most studies controlling for language fluency by excluding students who were not native speakers of English. Furthermore, there is currently little research on the different demographic characteristics of children with number difficulties compared with typically achieving children (Lewis & Fisher, 2016).

Research proposal

A preliminary study of 16 primary aged children found a combination of educational factors (such as a succession of supply teachers or absences), medical factors (such as temporary hearing loss) and social and emotional factors (such as family pressure) had contributed to the children's mathematics difficulties (Gifford & Rockliffe, 2008). In recognition of the external factors that may impact children's mathematical difficulties, the proposed research study will record the demographic characteristics of children with significant mathematics difficulties. Furthermore, to provide a comparison group, the study will also have the potential to extend the research to investigate the demographic and SES characteristics of children who are not identified as having significant mathematical difficulties.

The methodology to examine the characteristics of children with significant mathematical difficulties will consist of quantitative data analysis. In each of the schools involved in this research, the authors propose to analyse current and historical school-wide attainment data to identify children with significant mathematical difficulties. The authors propose to examine the current year 6 attainment data and, data permitting, track these children back through to reception. So, for example, as exemplified in Figure 1, with the current year 6 data, children 2, 7 and 9 would be identified as attaining significantly below national curriculum expectations and these

children will be tracked back to reception to see how their attainment history changes over time.

For the children who are found to be consistently attaining below national expectations, further demographic and SES data will be collected using a Pupil Profile Questionnaire (PPQ) developed by the authors. The PPQ will include a number of questions to capture pupil profile information including: SEND, gender, age (summer or spring born), English as an Additional Language (EAL), Pupil Premium (PP), Forces Families (FF), local authority, postcode, religion and ethnicity. In addition to the characteristics identified in Lewis & Fisher (2016), the proposed study will carry out a comprehensive literature review to identify and incorporate other factors (such as family size and position in family) that may be significant.

R(b)	Y1(h)	Y2(h)	Y3(h)	Y4(h)	Y5(h)	Y6(c)
1	1	1	1	1	1	1
				2	2	2
3	3	3	3	3	3	*3*
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	6	6	6	6	6	6
7	7	7	7	7	7	7
8	*8*	*8*	*8*	*8*	*8*	*8*
9	9	9	9	9	9	9

Key
Bold – Significantly below national expectations
Normal – At national expectations
Italics – Above national expectations

h – Historical data/year group
c – Current data/year group

Figure 1: Example of current and historical school-wide data

Similarly, the children identified as having mathematical difficulties in the current year 5, 4 and 3 would also be tracked back to reception and further demographic and SES data will be collected about these children using the PPQ. As such, the information gained about each child would form a data set. With an estimated 4-8 children identified across Key Stage 2 (KS2) in a single form entry school and the study expecting to include 6-9 schools, there is potential for 24 to 72 children to be considered.

It is expected that due to the removal of national curriculum levels in September 2014, there may be a 'disjoint' in the data analysed, with pre-2015 data consisting of national curriculum levels and post-2015 data consisting of varied school specific approaches to recording progress. However, for the purposes of identifying children with significant mathematical difficulties, the data analysis would be valid as the data is consistent in recording performance against national exceptions (regardless of changes to these expectations). Although the authors plan to use 'national expectations' as a key datum for identifying children with mathematical difficulties, they remain cautious as to the basis of these expectations. As such, the proposed research will also informed by data from standardised tests.

Profile of mathematical difficulties and strengths of individual children

Although mathematics is a very broad subject area, the topic specific research for significant mathematical difficulties has been narrow. A recent review of literature found that most research focuses on whether children know their *number bonds* and if they can carry out *multi-digit* calculation procedures, with some additional research examining children's knowledge of *counting sequence*, *number recognition*, *word problems*, *number principles* and *fractions* (Thouless, 2014). This leaves a number of other topic areas of mathematics that are rarely examined for children with significant mathematical difficulties, including: *multiplicative reasoning; geometry; measures;*

statistics; strategy use; mathematical communication; justifications; and *mathematical disposition* (Thouless, 2014).

Research proposal

The authors argue that a broad spread of mathematical topics need to be considered in this area of research to analyse and understand the mathematical profile of children's strengths as well as difficulties and to allow the research to move away from a deficit view of children (Dowker, 2003). A preliminary study of 15 primary aged children with dyslexia found that the children's *place value* knowledge impacted their ability to complete mathematical problems correctly despite having viable strategies to complete the problems (Thouless, 2014). By including aspects of *place value* in the assessment design, Thouless (2014) was able to draw specific conclusions relating to the children's understanding of the mathematics, which otherwise would have been limited to a statement that these children have difficulties understanding *word problems*. In recognition of this, when assessing children with significant mathematical difficulties, the authors will include a broad battery of questions to profile understanding across all key primary mathematics topics (under current national curriculum programmes of study) instead of limiting questions to *number bonds* and *multi-digit* calculations. By doing so, profiles of mathematical difficulties and strengths will be mapped for individual children. These profiles will also allow for comparisons of profiles across children with significant mathematical difficulties to draw out trends including common strengths and difficulties.

Different perspectives on children with significant mathematical difficulties

A preliminary study of 16 primary aged children found that interviewing teachers, parents and the children themselves revealed radically different and conflicting views about the nature of a child's difficulties, providing insights into the affective factors involved in mathematics education and the interpretivist approach required to consider different versions of 'truth' (Gifford & Rockliffe, 2008).

Research proposal

In recognition of the fact that different perspectives on an individual child's mathematical difficulties exist and that "all interpretations may be equally valid" (Gifford & Rockliffe, 2008:23), the proposed research study will carry out structured interviews to identify similarities and differences in perceptions for individual children across children and across stakeholder groups. The stakeholder groups considered will include the child, class teacher, teaching assistant and parents / carers.

Overview

Given the gaps identified in the literature, the proposed research aims to: (i) consider children with significant mathematical difficulties as individuals from different SES with different background characteristics and mathematical profiles, due to complex and interrelated causes, who show a persistent lack of progress; and (ii) examine the varied and possible conflicting perspectives on these children. Although children with number difficulties can have very different mathematical profiles and perspectives, evidence suggests that an approach based on detailed assessment, visual images, talk and reasoning is effective with all children (Gifford & Rockliffe, 2012).

Recommendations from Gifford & Rockliffe (2012), drawing from research on early predictors of mathematics achievement and from practitioners working with children with dyscalculia, indicate the effectiveness of detailed assessment and monitoring. These strategies will be recommended generally for effective maths teaching and to promote integration in mainstream provision. Working with teachers would allow for development of practical interventions which are consistent with whole class teaching and inclusion policies and for in-depth evaluation of different aspects of number learning.

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